# PRACTICAL OBSERVATIONS

ON

THE MECHANICAL STRUCTURE,

MODE OF FORMATION,

THE REPLETION OR FILLING UP,

AND

THE INTERSECTION AND RELATIVE AGE

OF

# MINERAL VEINS;

WITH THE

APPLICATION OF

SEVERAL NEW THEORETICAL PRINCIPLES

TO

THE ART OF MINING.

BY JOHN LEITHART,

MINE AGENT.

WITH NUMEROUS ILLUSTRATIONS.

LONDON:
JOHN WEALE, 59, HIGH HOLBURN;

NEWCASTLE:
CURRIE AND BOWMAN.

1838.

In Memoriam
Arthur Eaton

PRINTED FOR THE AUTHOR, BY J. BLACKWELL
AND CO., NEWCASTLE UPON TYNE.

TO

JOHN BUDDLE,

OF WALLSEND, ESQ.,

FELLOW OF THE GEOLOGICAL SOCIETY,

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS,

WHOSE EXPERIENCE AND ABILITY

AS A MINING ENGINEER

IS ONLY EQUALLED BY HIS DESIRE TO ENCOURAGE

THE EFFORTS OF OTHERS WHO ARE

EMPLOYED IN THE INVESTIGATION OF

SUBJECTS PRACTICALLY CONNECTED WITH THE

PROGRESS OF MINING,

THE FOLLOWING OBSERVATIONS

ON MINERAL VEINS

ARE, WITH PERMISSION,

RESPECTFULLY INSCRIBED,

BY THE AUTHOR.

ALSTON MOOR, AUGUST 10, 1838.

Page 10, line 8 from top, *read* bent up, *instead* of rent up; and line 9 bent down; line 19, *for* bent, *read* fissure.

Page 24, line 12 from top, *for* correct, *read* erect.

Page 39, line 11 from bottom, *read* immediate, *for* intermediate.

Page 47, line 2 from bottom, *for* salt, *read* salts.

Page 49, line 16 from top, *for* intersection, *read* interduction.

Page 55, line 12 from bottom, *for* hermo, *read* thermo; and at line 11, *for* discharged, *read* discharge.

Page 57, line 3 from top, *read* on, *for* or; also, line 12, for or, *read* on; also, line 19, *read* flowing towards A., instead of flowing in at M. towards A.

Page 59, line 8 from bottom, *for* angles, *read* angle.

Page 62, line 11 from bottom, *read* with the, *for* with this; and at line 6, *read* current is moving, *instead* of current in its moving.

Page 64, line 5 from top, *read* on, *for* or.

Page 70, line 2 from top, *read* miner, *for* miners.

Page 72, line 14 from top, *read* east and west fissures, *instead* of east and fissures.

Page 73, line 7 from bottom, *for* where even, *read* where ever.

Page 83, line 3 from bottom, *for* principles that which will, *read* which will.

# PREFACE.

The circumstances which first directed the Author's attention to the phenomena of strata and mineral veins are detailed in a paper on the Stratification of Rocks, submitted to the Geological Section at the Meeting of the British Association, held at Newcastle, in August, 1838 ; it may suffice here to mention that being a native of, and having always lived in, the interesting mining district of Alston Moor, a large portion of his time, from his infancy, was spent in the mines. He had not the good fortune to obtain the usual advantages of education, and would perhaps have remained altogether uninstructed as regards literature, but for the active and generous aid and friendship of the late John Dickinson, Esq., of Low Byer, to whom he owes a deeply-felt and lasting gratitude. A Sunday School, promoted by Mr. Dickinson, and which, nearly to his dying day, at an advanced age, had the advantage of his constant and zealous superintendence, was the only school (in the ordinary acceptation of the word) that the author ever attended. Opportunities of reading were afforded to the miners by Mr. Dickinson, who not only lent books to them, but afforded, by kind and judicious

advice, and by a life of unwearying and active benevolence, a constant example of upright principles, of diligent research, and of plain and unpretending manners. These opportunites in some measure compensated the want of the ordinary benefits afforded by day schools for general learning. In the meantime the perusal of various works had given the author a desire for knowledge, and the sciences of Astronomy and Geology particularly attracted his attention. In the latter he had daily opportunities of witnessing the actual phenomena of veins when at work as a miner. About ten years ago he had many opportunities of becoming well acquainted with the exact relative position of all the known veins in the manor of Alston Moor and adjacent districts, by assisting in the extensive Mining Surveys then in progress by Mr. J. Dickinson and Mr. Thomas Sopwith, and by drawing several of the Mining Plans and Sections in their Office. Being much employed as a mining agent, and occasionally visiting distant districts, he became anxious to apply theory to practice, but found many and often insuperable difficulties. At length several speculations on electrical and galvanic phenomena seemed to open a new field for explaining many subterranean phenomena, and, after some years of patient investigation, which formed a recreation for his leisure hours, he at length arrived at some definite experimental results respecting the formation of strata, and the structure of mineral veins, as well as on several other subjects. At the recommendation of Mr. Sopwith,

he has been induced to submit his observations on the formation of stratified rocks to the British Association, and also to offer his views respecting mineral veins to the public in the present volume. It remains only to be mentioned that Mr. Buddle, who is ever anxious to encourage a spirit of enquiry, has, with his accustomed liberality, given the author his friendly aid and encouragement.

The suggestion to publish the present volume having been made only a few weeks previous to the meeting of the British Association at Newcastle, the time has not admitted of a careful revision of the press by the Author. From the same cause Mr. Buddle has not had an opportunity of attentively perusing the work, and his patronage of it must therefore be considered as being given to it as the investigations of a practical miner, without having had the means of fully considering how far the principles advanced by the Author are in accordance with the phenomena from which they are deduced. In conclusion, the Author trusts he may venture tc say that many of the actual phenomena of mineral veins are here presented to view—that the plans and sections of veins, drawn from actual observation, are more detailed and minute than have yet been given to the public. He has at all times been willing to impart to others whatever information he has obtained; and while he offers his views with a strong confidence as regards practical facts, he is fully sensible of the difficulty of attempting the solution of the difficult problem

presented by the phenomena of mineral veins. His speculations, he trusts, will at least invite a spirit of enquiry, and it will indeed afford him a high gratification if he shall be considered as having advanced even a single step towards a further connection of the physical sciences with the art of mining. He may perhaps be allowed to observe, that the circumstances already mentioned may plead in his behalf for any occasional errors or defects of composition. The condemnation of generous criticism will in some measure be softened towards the literary imperfections of an Author whose only book-learning was that of a Sunday School, and whose mathematics were chiefly studied by using only a mining shovel and a piece of chalk. On the other hand, as regards facts and practical deductions, the Author can claim no such indulgence, for in respect to them his education has been in the best of all schools—the mine itself.

# INTRODUCTION.

In none of the sciences, perhaps, have we a greater number of phenomena, or a wider range of research, than in the science of geology; yet in none have we less of clear and certain knowledge. What appears to be the main obstacle to our progress in this department of knowledge is, that the agents which nature employs in the production of geological phenomena, are either placed beyond the reach of observation, or are so slow and minute in their operation as to elude it. This being the case, the changes which the earth's surface appears to have undergone, as well as the agents that have produced them, are as yet imperfectly comprehended. Another obstacle to our progress in geological science is, the great diversity of the phenomena it embraces, and proposes to explain. In some parts of the earth's surface, we have a regular order of succession in the beds or layers forming its crust; in others, the materials are tumbled together in great confusion. In some parts of it, the beds have their planes of stratification parallel to the horizon, in others they are perpendicular to it. In some parts the strata are rent into innumerable fragments; while, in other parts, they are in an

entire state. In particular parts and strata, these rents or fissures are filled with matter of a rocky character; in other parts and strata, with the ores of the different metals, and other crystalline earthy minerals; and, lastly, some of the fissures are filled with the bounding rocks in a decomposed state; others with clay, sand, gravel, &c., with a multitude of other phenomena, which no geological theory has yet fully embraced, or which have been clearly explained by any admitted system of science.

All Geological theories must, from the very nature of the subject, be in a great measure conjectural. For we have a system of things presented to our view, evidently the work of agents acting at distant intervals of time, and this, apparently, not in any regular progression or harmony. The operations of each successive era obscuring, or partially destroying, the productions of the preceding; so that we have not before us the perfect result of any one concurring system of natural operations, but a mass of confusion and disorder, having rather the character of ruin than a perfect structure; yet we admit that the simple materials of the earth's crust, and the laws of nature, have continued the same in all ages—the great advances in physical science, and the extensive researches into the natural history of the earth already made, render it highly probable, that before long, the causes and methods of all these changes will be fully determined. As the architect, having learned certain rules and pro-

portions by the study of the less dilapidated remains, can reconstruct the mouldering fragments of a ruined temple; give a correct idea of its form and extent, and can restore, even in detail, its ornaments in all their pristine beauty; and as the naturalist, having found a single bone of an animal, the whole species of which may have been for ages extinct, can tell not only what were its habits and its external appearance, but can even detail the structure of its internal organs: so the geologist, having made himself acquainted with the known laws of nature, and the phenomena exhibited in the various formations which constitute the crust or surface of the earth, endeavours to restore them, in idea, to their primeval state; and by the relative position of their disjointed parts, or any other discernible marks of change, to trace out the causes of these great convulsions of nature, or the agents in those more minute and protracted operations by which the present state of the earth's surface has been induced.

## SECTION I.

### ON THE MECHANICAL STRUCTURE OF MINERAL VEINS.

MINERAL Veins are spaces in the rocks, constituting the surface of the earth, filled with various materials which are different in general from the substance of the rocks which they traverse.

In this definition we have two distinct objects of inquiry—the *formation of the spaces in the rocks*, and the *subsequent filling up of them*. The former of these subjects, viz., the formation of the spaces, will constitute the first object of inquiry.

The formation of mineral veins, both as regards the advancement of science and its practical utility, is one of the most interesting and important departments of geological inquiry. As might, therefore, be expected, much has already been written on the subject, and different theories have been advanced; yet it is a sufficient stimulus to further investigation that none of these theories have been approved by any large majority, either of scientific geologists or practical miners.

The first requisite in attempting to establish any theory is to give a full view of the phenomena to be accounted for, so far as they are known.

Of the spaces in which the contents of mineral veins are found, there are a great variety, both as regards their form and position; and names have been given to them by miners, expressive of these varieties, as Rake vein, Pipe vein, Flat vein, Strings, &c. They may be classed under two general heads—the *Fissuriferous Vein* (or mineral fissure), and the *Tubular* (Tube vein), the first including those which have the appearance of a fissure, or rent in the strata, extending to a great length, and generally to an unknown depth: the second, those that have the form of an irregular tube or perforation, either being nearly horizontal in one stratum, or passing more or less obliquely from the surface downwards, to an unknown depth.

## OF THE FISSURIFEROUS VEIN,

### OR MINERAL FISSURE.

Fissuriferous veins are the most prominent, and the phenomena presented by them are the most various and complicated. These veins, therefore, demand particular attention, especially as the phenomena have as yet been but partially exhibited, and for many of them no rational explanation has even been attempted.

The longitudinal course or bearing of these veins or fissures is seldom, if ever, in a perfectly straight line; but, though crooked in detail, they, for the most part, preserve in general a direct average

bearing through their whole course, as in Fig. 1; yet occasionally considerable deviations take place in the general bearing, as in Fig. 2.

As it regards the direction of veins, though divided into two classes—North and South veins, and East and West veins, accordingly as their general bearing approaches to these directions—yet in the same district variations are found running in every possible direction.

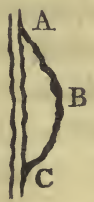
The width of the vein or fissure is not uniform throughout its whole length. Some veins, at successive intervals, open out to a width of from two or three feet to as many yards, and then contract to a mere joint or crack in the strata, as in Fig. 3; others continue with little variation in width through their whole course.

The beginning or termination of a vein or fissure, longitudinally, is seldom explored. Where this has been done, the vein appears to commence at the one end abruptly, and after continuing for a greater or less distance in an entire state, it begins to send out small veins, or strings, as the miners call them, from either side, at acute angles; and, finally, to terminate, or be lost in a number of these strings, as shown below.

The downward course of veins varies from the perpendicular to an angle of 45°; but their inclina-

tion to the horizon, or *hade*, as it is commonly called, is not uniform. In an alternating series of strata the hade is greater; that is, the vein inclines more towards a horizontal position in the soft strata than in the hard, as shown in Fig. 5.; and it sometimes occurs that the vein, in passing a stratum of coal, or soft clay, takes the direction of the stratum for a greater or less distance, as in Fig. 5; the vein being much contracted, and sometimes almost entirely disappearing, in this horizontal part of its course. As the vein descends deeper into the earth, where the strata, being under great pressure, are harder, and where the strata differ less in induration and density, the inclination or hade becomes *less*, and *more uniform*.

Veins sometimes give off strings in their vertical course, as well as in their horizontal; and sometimes a string of this kind goes off from the overlying side of the vein, and returns into it again in the form of a segment of a circle, as is shown below at A B C.




The strata on one side of a vein are generally found at a higher level than on the other: and most frequently the underlying side is on a higher level

than the overlying side, as in Fig. 5, &c. In this case, if the hade or inclination is not uniform, as in Fig. 4, but varies, as in Fig. 5, in an alternating series of strata, *the vein has a greater width in the hard strata*, or those in which it has a more erect position, than in the soft, where it is more inclined.

Sometimes, though rarely, it occurs that the strata on the overlying side are on a higher level than on the underlying; and when the hade or inclination is not uniform, as in Fig. 6, but is variable, as in Fig. 7, *the vein is of greater width in the soft strata*, where it is more inclined than in the hard, where it has a more erect position.

To distinguish these two kinds of fissuriferous veins—the former, or those which are *more capacious* in the *hard* strata, may be called *hard, or erect Capacious Veins;* and the latter, which are *more capacious* in the *soft* strata, may be called *soft, or inclined Capacious Veins.*

This distinction is entirely new; and though, perhaps, of little consequence as regards geological science, it is of the utmost importance in mining. The *hard, or erect capacious veins, are by far the most numerous, as well as the most productive of metallic ores;* the soft, or inclined capacious veins, being generally of a poor and deceitful nature, and when productive of ore, *it is not found in the same strata* as in the hard, or erect capacious veins. By a due attention to these facts, an immense amount

of the capital which has been thrown away in useless trials might have been saved.

The strata forming the sides of the vein or fissure are not only on a different level, but immediately adjacent to the vein they have a different position, being bent upwards on the one side, and downwards on the other, as shown in Fig. 8. This may be called *the bur of the vein.* In some veins the bur is very conspicuous; but in others it is partially or wholly obscured by the extensive chemical and mechanical changes which have taken place in the rocks at the sides of the veins.

It is to be observed, that the above illustrations apply only to the formation of the original fissure. Both its form and capacity are very considerably modified, as will hereafter be explained.

The *bur*, and *throw or displacement* of the strata, as well as the *capacity* of veins, are found, with few exceptions, to be greatest at or near the surface, and gradually decrease in descending into the earth; and though a vein may never have been traced so deep that the bur and throw wholly disappeared, yet, from their regular decrease, it is presumed there must be a point where they come to nothing: whether the vein may terminate at the same point, will probably for ever remain matter of conjecture.

The bur and throw of veins, or the displacement of the strata, are not to be conceived as an absolute shifting of them, but the effect of a mechanical

agitation of the particles of the strata on the one side of the fissure different to that on the other, and also to a different degree of pressure.

The structure of veins or fissures may be further distinguished from the position which the strata have near to them.

When the vein, Fig. 8, has the strata on the underlying side rent upwards, and on the overlying side rent downwards, it may be called a *bur vein.*

When the vein, Fig. 9, has the strata on the underlying side on a higher level, and inclined to it, as at H A and G F, and on the overlying side on a lower level, and declining from it, as at A I and F G, it may be called an *overlying subsident vein.*

When the vein, Figs. 10 and 11, has the strata on the overlying side on a lower level, and inclined to it, as at I A and G F, and on the underlying side on a higher level, and either having an inclined or horizontal position, as at W A, Fig. 10, and H A, Fig. 11, it may be called an *underlying subsident vein.*

When the vein, Figs. 12 and 13, has the strata on the overlying side on a lower level, and declining from it, as at A J and *f g*, and on the underlying side the strata on a higher level, and either horizontal or declining from it, as at A W, Fig. 12, and A H, Fig. 13, it may be called an *underlying heave vein.*

When the vein, Figs. 14 and 15, has the strata on the overlying side on a higher level,

and either horizontal or declining from it, as at F V, Fig. 14, and *f g* and *a g*, Fig. 15, and on the underlying side on a lower level, and having a position inclining to it, or horizontal, it may be called an *overlying heave vein.*

In order to illustrate how this difference of width or distance between sides of veins in different strata takes place when they traverse an alternating series of hard and soft strata, let the straight line A B C D E F, Plate 3, Fig. 16, be a rent, having an uniform inclination or hade in both the hard and soft strata. Then, if on the underlying side of the fissure the strata are bent up over the points H and G, and on the overlying side are bent down over the points I and J, in this case, the sides of the fissure will be in contact throughout; that is, in both the hard and soft strata, or in other words will be mathematically divided. But if the vertical course of the vent be inflected, as in Fig. 24, and having the strata bent up on the underlying side, and bent down on the overlying side, then will the sides of the fissure be only in contact in those parts in which it has the greatest inclination, that is, in the soft strata. For if the point G be drawn into the position *a* A, then the point *m* will be drawn into *b* B; the point *n* into *c* E; the point *o* into *e* E; and the point *p* into *f* F; and hence in the hard strata A B, C D, and D E, will be formed the fissile cavities *w* and *s*.

Again, if the fissure has a uniform inclination, as

in Fig. 17, and the overlying side be moved down from *v'* to V, or (which is the same thing) from U' to U, in the line of direction of gravity, the sides of it will be in contact throughout, that is, in both the hard and soft strata, as has been shown in the case of Fig. 16. But if the vertical course of the fissure be inflected, as in Fig. 25, then the sides of the fissure will only be in contact in those strata in which it has the greatest inclination, that is, in the soft; as has been shown in the case of Fig. 24.

Again, if the fissures, as in Figs. 18, 19, 20, and 21, have a uniform inclination, and their overlying sides on a lower level than the underlying, then the sides of the fissures will be in contact throughout; that is, in both the hard and soft strata, as has been shown in the case of Fig. 16. But if the vertical course of the fissures be inflected, as in Figs. 26, 27, 28, and 29, then will the sides only be in contact in those strata in which the fissure has the greatest inclination; that is, in the soft strata, as has been shown in the case of Fig. 24.

Again, if the fissures, as in Figs. 22 and 23, have a uniform inclination, and the overlying side on a higher level than the underlying, then will there be formed between their sides the fissile gashes, or chasms, *s s*, of uniform width from top to bottom, provided the overlying side possesses such a degree of rigidness as not to crush. But if the vertical course of the fissures be inflected, as in Figures 30 and 31, then will the irregular formed cavity *s w s*,

be produced between the sides of the fissures; the cavities being much larger in those parts which have the greatest inclination, that is, the soft strata, than in the hard, or those in which the fissure has the most erect position.

An important consequence deducible from the fact of veins having a more erect position in the hard strata than in the soft, when they traverse an alternating series of them, is, that in a homogeneous mass of rock (such as the primary rocks) the vertical course will be curvilineal. For the increase of induration and density in a homogeneous mass of rock cannot take place suddenly, but must gradually increase with the depth below the surface; therefore veins in their downward course through the primary rocks are bent or deflected in each element of their route from the surface towards the perpendicular, and hence must be more or less curvilineal. So that if it be admitted that a difference of level of the corresponding parts of rocks on the opposite sides of the fissuriferous vein, be a general property of it, then will veins in the primary rocks have the following mechanical characters.

In order to illustrate the mechanical structure of veins in the primary rocks, admitting the corresponding parts of the rocks to be on different levels on the opposite sides of them, and that their vertical courses are curvilineal, let A B, Fig. 32, be the vertical course of the vein; then if the rock on the underlying side is bent up, and on

the overlying side is bent down, there will be formed between the sides of the fissure the meniscous shaped cavity *s*, the sides of it being in contact at both the superior and inferior extremities of the fissure. Then if veins in the primary rocks have their corresponding parts on the overlying sides on a lower level than on the underlying side, as is the case with them in the secondary strata, there will be formed between the sides of the fissures the meniscous shaped spaces *s s*, &c., in each of the Figs. 33, 34, 35, 36, and 37, similar to that of *s* in Fig. 32. But in case the fissure has its overlying side on a higher level than the underlying side, as in Figs. 38 and 39, then will there be formed the concave-shaped chasms *s* and *s*, which are open both at the superior and inferior extremities.

Having, in the foregoing remarks, pointed out the most obvious mechanical features of Fissuriferous Veins, I shall conclude this description by referring to a diagram which exhibits the phenomena which they present in traversing the strata in the mining district of Alston Moor. Plate 6 is a section of the strata in the above district, from the top of the Whin-sill to the top of the Fell-top limestone, in which is presented the vertical course and mechanical structure of a *hard*, or *erect capacious vein*, Fig. 40, and of a *soft*, or *inclined capacious vein*, Fig. 41, each having the strata on one side of it four yards higher than on the other. The phenomena which these veins present in traversing each stratum

have been stated in treating of the general properties of this species of vein.

Having described the structure of the fissuriferous vein, I shall now point out the mechanical structure of the common *pipe or tubular vein*, the *radiated pipe vein*, and the *lateral embedded*, or *flat vein*.

In the common pipe or tubular vein, there are two species, the *embedded* and the *disruptive*. The former, or embedded, has a position conformable with that of the stratum in which it is found, as in Fig. 42; and the latter, or disruptive, has a position more or less vertical, so as to pass through the different strata, as in Fig. 43: both this and Fig. 42, being longitudinal sections of the vein.

The most prominent mechanical features which the common pipe vein presents, are its zig-zag longitudinal course and variable size, and also its leaping off from its preceding course first to one side and then to the other, in the most capricious manner. The usual form of the embedded pipe vein is an elongated ellipsoid, as in Fig. 44; and that of the disruptive an irregular cylinder, as in Fig. 45, both of which are sections across the veins.

The next order of vein is the radiated pipe vein, Fig. 46. This vein appears to be composed of the two preceding orders of veins, viz., the fissuriferous and the common pipe vein. It may either be the result of the intersection of several short fissuriferous veins at one point, or it may be formed by the rending of the circumscribing rock at the

time of the formation of the common pipe vein. The mechanical structure of this order of veins may be studied by referring to what has been stated with regard to the two preceding orders.

The last order of veins is the lateral embedded, or flat vein. This vein is never met with but in connection with some fissuriferous vein, and has always a position conformable to that of the stratum (most commonly limestone) in which it is embedded. In order to illustrate the mechanical features and connection of the flat vein with the fissuriferous, let C D be a part of such vein traversing the limestone stratum M N, Fig. 47; then are the wedged-shaped cavities *n o* and *p q* on the one side of the fissuriferous vein, and *r s* and *t v* on the other, the lateral embedded, or flat veins, extending to a limited but variable distance from the fissuriferous vein. From what has been stated of the flat vein, it is plain that it is not a regular stratiform mass, as its length, breadth, and thickness are variable, as, likewise, from its not always being found to accompany the fissuriferous vein.

## SECTION II.

### ON THE FORMATION OF THE FISSURES, OR SPACES OF VEINS.

Having examined the principal features of the mechanical structure of veins, we are next, from these data, to enquire by what kind of force such effects could be produced. It would not accord with the limits or the object of this work, to enter into a formal review of all the theories which have been proposed to account for the formation of veins, but it may be deemed necessary to notice a few of the most popular.

Some geologists have entertained the idea, that the rocks traversed by veins were in a humid state, and that veins are cracks or rents formed by a diminution of their volume in drying.

That from desiccation and other causes of a diminution of volume, the strata might be separated into blocks, or fragments, is beyond doubt. And it is found that they are so divided by cracks, called cutters, joints, or backs; but the form and size of these blocks, and consequently, the direction, as

well as the number of the joints, varies in the different strata, each evidently following its own peculiar law of consolidation, and there does not appear to be any connexion between those which occur in one stratum and those of another. How, then, can we conceive that the cracks or joints in each stratum, should happen to come so exactly under those of the stratum immediately above, and should run exactly in the same direction for miles, so as to form a continuous fissure through a hundred beds of different strata?

Again, no crack or opening could take place in any stratum, until it had attained such a degree of rigidity, as would prevent it from yielding to the superincumbent pressure; for it is impossible that a space could be formed in a mass under pressure, while the compressing force was capable of causing its molecules to move among themselves. And as the strata are all under pressure, increasing from the surface downwards, each stratum must have acquired a certain degree of induration, according to its depth, before any space or open fissure could be formed in it.

Hence, we might expect the rents to be much more numerous, and more open near the surface than below; also larger and more numerous in the hard strata, than in the soft. And this condition of the rocks corresponds exactly with that which they assume from the joints or backs

before mentioned, which are altogether distinct from the structure of mineral veins. But besides this, a mere cracking of the strata from desiccation, or any other cause, will afford no explanation of *the bur*, *the throw*, and others of the more striking phenomena presented by mineral veins.

Another idea entertained respecting the formation of veins, is, that they are cracks consequent upon the subsidence of a mass of the strata, either from the unequal yielding of the inferior parts, or the withdrawal of some other support from beneath them. Though the unequal resistance of the inferior strata to the superincumbent pressure, while the whole was in a humid state, might very naturally account for the inequalities in the thickness of beds, which so frequently occur, and also for their waved, or undulating positions, yet neither that, nor the sinking down of the strata from any other cause, will account for the phenomena which veins present in their mechanical structure.

A subsidence might cause a mass of the surface to be detached, and to slide down, as is shown in Fig. 4; but in this case, the difference between the level of the strata on one side, and that of the same strata on the other, that is, the throw of the vein, would be the same from the top to the bottom of the vein; but this is not the case; see Fig. 5, a case of frequent occurrence, which could never be explained on this supposition.

Another theory is, that by an expansion of the

interior parts of the earth, by heat or some other cause, the crust of the earth has been forced upwards, and thus cracked and broken. Then, as the mechanical action of this upward pressure is exactly the reverse of that considered in the last paragraph, the same arguments will apply to both.

There are, indeed, fissures, or faults, which might rationally enough be referred to a simple sliding down of a mass of the strata on one side, or the forcing of it up on the other; but no motion of a mass of the earth's surface, either upwards or downwards, can account for the existence of a point (where the fissure lies in a stratum, see Fig. 5,) in a vein where is no throw, while there is a throw above and below that point.

Seeing then that no mere cracking of the strata from desiccation, internal heat, or any other cause of expansion, or contraction; nor yet any sinking down, or forcing up of the earth's surface, will satisfactorily account for the formation of the fissures called veins; the question arises, whether there be any known force sufficiently powerful to produce such, and the *modus operandi* of which corresponds with the complicated phenomena to be explained.

Some of the phenomena, as the zig-zag nature of the downward course of veins, the bur, as also several others, and likewise the chemical changes which have taken place in the adjacent rocks, bear a striking analogy to the course and effects of a powerful *Electrical* discharge; and it is the

object of the following pages to show that such an agency is competent to afford a fair and rational explanation of the phenomena detailed in the preceding section, on the mechanical structure of veins.

That the electric fluid pervades all material bodies, and is extensively concerned in the operations of nature, has long been acknowledged. The most brilliant of modern discoveries in chemistry are those which have developed its influence in the atomic combinations of matter; and attributing to it the formation of the fissures or other spaces occupied by the contents of mineral veins, would be but another step in the generalization of its agency in the economy of nature.

The way in which the electric fluid is accumulated in the interior of the earth, and its discharge effected, is an inquiry of great interest and importance; and in an attempt to explain it, the structure of the earth's superficies must be first known.

The earth's crust is, for the most part, composed of beds or strata, piled one over the other, of greater or less thickness; and at the divisions between them, or where one stratum ends and another begins, there is always a thin layer of some soft, tenacious, and flexible matter, having a laminated texture, the prevailing constituents of which are clay, talc, and mica, all of which are either very inferior, or non-conductors of electricity; so that these thin layers will act as insulators to the dissimilar electric masses

of strata, in which strata, particularly those near to the surface, the electric fluid will be accumulated until its intensity becomes so great at some point as to burst asunder the insulating mediums.

On the eruption first occurring, large areas, or even oceans, of the electric fluid would be suddenly liberated and brought into action, which would rush through the rent with immense force and violence, not only tearing the strata asunder, but also causing a violent vibration among their particles; and as the opposite sides of the rent will be subject to a difference, not only of mechanical agitation of their particles, but also of pressure, the one side will have its corresponding parts depressed below that of the other, the difference of level being greatest at the surface.

Having shown the way in which electro-mechanical action may be brought into play in the interior of the earth, I shall now proceed to show the most striking analogies between the effects of a discharge of electricity, and the phenomena of mineral veins, considered in regard to their mechanical structure.

The effects of an electric discharge through an imperfect conducting substance are such as would be produced by a material agent being driven through it with great force and velocity, separating the particles of the body in the line of its course, thereby producing either a perforation, or a rent, or both, according to the nature of the discharge and of the substance.

The sides of veins, when undecomposed, are not in a ragged state, as if the strata had been slowly and progressively torn asunder, but are, in general, well defined, as if they had been split by a sharp instrument, or by the instantaneous operation of an immense impulse.

The course of an electric discharge through a system of bodies of different conducting powers is in a zig-zag direction, and leaping sideways at the several surfaces of junction of the bodies.

For as bodies of inferior conducting power oppose greater resistance to its passage through them than those of superior conducting power, therefore in passing out of a body of superior into one of inferior conducting power it will be deflected outwards from the line of its previous route when the plane of position of the bodies is not perpendicular to the route of the electricity; but in passing out of a body of inferior into one of superior conducting power, it will be bent inwards from the line of its previous route: for the momentum of impulse of the discharge may be resolved into two forces—one acting in the direction of the plane of separation of the compound conductor, the other perpendicular to that plane—consequently the greater the difference in the conducting power of the parts of the compound conducting body, the greater will be the inflections in the line of the route of the electricity. This property of electricity is exemplified in the crooked course of lightning through the air, and in

its irregular and seemingly capricious route when it strikes buildings, &c.

To apply this to the course of veins. The calcareous strata being earthy salts, are better conductors of electricity than the siliceous; and the siliceous are in general better conductors than the argillaceous. And each of these species of strata have their conducting power increased in some certain ratio to the increase of their induration. It has been observed, page 7, that in an alternating series of beds of limestone, sandstone, and shale, or plate, the veins have a more correct position in the limestone (hard), than in the sandstone (softer), and also more correct in the sandstone than in the plates (softest); it appears, therefore, that the zig-zag character of the vertical course of veins through an alternating series of strata of different conducting powers, is exactly similar to the course of electricity under similar circumstances. Another cause which would concur with the difference in the conducting powers of the strata to produce the inflected condition of the vertical course of veins, is that of a difference of their electric state—the shales, or plates, being, for the most part, positive as regards the sandstones, and the sandstones positive as regards the limestones.

Again, veins have a greater inclination in strata which are near the surface, than they have in the same, or similar strata at a greater depth; and in a homogenous mass of rock of great thickness, such

as the clay, slates, &c., a vein in its downward course is deflected towards the perpendicular in each element of its route, its course being curvilineal: the nature of the curve depends on the increase of induration, which is in exact accordance with the law, that the conducting power of rocks increases in some certain ratio with their increase of induration and density.

The passage of electricity produces an expansion of the parts of a body in the line of its route. When a discharge is sent through a card, the edges of the perforation are bent or burred, the part forming the margin of the perforation being expanded; and, consequently, forced outwards, and the protrusion is always greater on the side of the card next to the negative pole. If the discharge be sent through a quire of strong paper, the amount of the effect will be found to be different at different depths from the surface. One edge of the perforation being burred in one direction, and the other edge being burred in the opposite direction, as if it had been made by drawing two threads through in opposite directions.

These effects bear a striking resemblance to the bur of veins; and a little further consideration will suffice to shew, that the throw and displacements of the strata, in the neighbourhood of veins, may be accounted for on this principle. It appears that the immediate effect of a discharge of electricity through a substance, is to excite a commotion among the

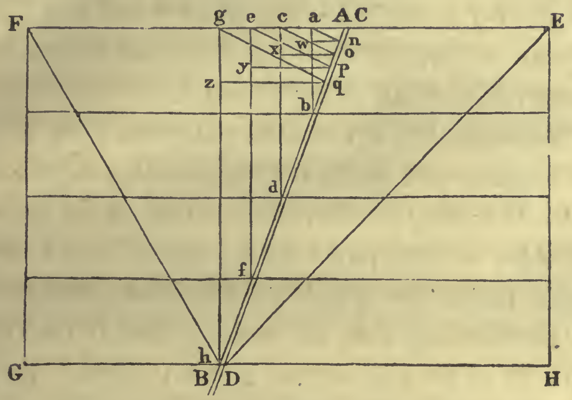
particles of the substance in the line of its route; and, consequently, to cause an expansion and displacement of the parts relatively to each other. The magnitude of the effects of this action from an equal discharge, will vary considerably in different substances, being greatest in those of small conducting power. Suppose a violent commotion and expansion of this kind to have taken place in the rocks, forming the immediate walls of veins at their formation, it is evident that the parts thus expanded, and occupying a greater space, must have been forced out of their former position in one way or another; and this would necessarily give rise to a bending of rocks in opposite directions, they being raised up on the one side of the fissure, and thrust down on the other, which is in exact accordance with the phenomena they present.

Another phenomenon, accompanying the passage of electricity through bodies of low conducting power, is the evolution of heat, which is a phenomenon that veins frequently present in their walls.

In order to shew the relative proportion of the compressing force exerted on the overlying side, to that on the underlying side, when the fissure has not an erect position;

Let A B D C (see the accompanying Diagram,) be a fissure; and A, $b$, $d$, $f$, and $h$, five points at different depths in it; then, at the point $h$ the total pressure will be $g\ h$; at the point $f$, $e\ f$; at the

point *d*, *c d*; at the point *b*, *a b*; and at A, nothing.




But as the direction of the pressure is oblique to the vertical course of the fissure, it may be resolved into two forces, the one acting vertically, and the other horizontally; or on the plane C D. Then, if there be drawn *g q*, *e p*, *c o*, and *a n*, each perpendicular to the plane of the fissure A B, and there also be drawn *q z*, *p y*, *o x*, and *n x*, each parallel to A *g*, or the horizon. Then from the law of the resolution of forces, *z h* will be the part of the total pressure *g h*, acting on the overlying side A B G F, at the point *h*; and *y f* will be the part of the total pressure *e f*, acting on the same at the point *f*; and in like manner, will *x d* and *w b* be the respective parts of the total pressures *c d* and *ab*, acting on the same side at the points *d* and *b*. Again, in agreement with the law of the resolution of forces, will *z g* be the part of the total pressure *g h*, acting on

the underlying side at the point *h*; and *y e* will be the part of the total pressure *e f* acting on it at the point *f*; and, likewise, will *x c* and *w a* be the respective parts of the total pressures *c d* and *a b*, acting on it at the points *d* and *b*.

Consequently, if the total pressures *g h*, &c. be the diameter of a circle, the compressing force acting on the overlying side is to that acting on the underlying side, at any point, as the versed sines of the angles which the plane of the fissure makes with the horizon, viz., as the versed sine of the angle E C D is to that of the angle F A B. Hence, the reason why the strata on the overlying sides of veins, are (with few exceptions) on a lower level than on the underlying side; also, why the throw of veins, or the difference of level in the corresponding strata on the opposite sides of them, are variable; generally decreasing progressively as the depth increases.

Having examined the most striking analogies between the effects of electricity, and the mechanical structure of the fissuriferous veins, the tubular or pipe veins are next to be considered.

The difference of structure between the fissuriferous and tubular, or common pipe vein, may be explained from the nature of the electric discharge being different at their formation,—the formation of the first being the result of the discharge taking place from a large surface; the latter, to its taking place from a point. For when electricity is dis-

persed over a large surface, and a discharge takes place from it, the body is rent, and the direction of the fractures is generally rectangular to each other; as for instance, when the electricity forces a passage for itself through the substance of an over-charged jar, or a plate of glass; but if the discharge is effected by a point, a perforation is produced; if, however, the discharge from the point be not effectually restrained from dispersion, (by some non-conducting substance, as oil, resin, &c.) the perforation will have a number of small fractures proceeding from its margin. Therefore, according to the manner in which the discharge is produced, we will have, as the effect, *a fracture*, or the *fissuriferous vein*; a *simple perforation*, or the *common pipe vein*; or a *splintered perforation*, or the *radiated pipe vein.*

Another phenomenon, which the two latter species of vein present in their structure, analogous to the mechanical effects of electricity, is the twisted character of their longitudinal courses, like that of a corkscrew.

The last species of vein, the formation of which is to be considered, is the lateral, embedded, or flat vein. The position and connexion of this vein with the fissuriferous is strikingly analogous to what, in electrical science, is called the lateral discharge, viz., to the tendency which a high charge of electricity has to diverge, or spread out side-wise, when circumstances admit of it, from the direct line

of its route; more particularly, when much obstructed in its passage.*

I have thus pointed out the most striking analogies which subsist between the mechanical effects of electricity, and the phenomena which mineral veins present in their structure, in both the secondary and primary strata; and the resulting phenomena in both are so exactly similar, or perfectly identical, to those of electricity, as to lead to the conclusion, that the formation of the spaces, which the contents of veins occupy, is the effect of electrical agency.

But if any other argument were wanting to establish the electrical theory of the formation of mineral veins, it is furnished by the fact, that there is no other single known agent in nature, whose power and mode of action are competent to the production of the vast and complicated phenomena which veins present in their mechanical structure.

It may not be amiss, in this place, to notice some other geological phenomena connected with the present inquiry, which may be explained in a more

* In the limestone strata, at least at the random, or position in which the flats occur, the limestones in those parts are of a cavernous character and columnar texture, while above and below the flat beds they have always a laminated and compact texture. In those limestones in which this property is wanting, there have not as yet been any flats discovered; but there are instances of this property in limestones where no flats occur.

satisfactory way from electrical agency, than from any other cause.

The fact which first presents itself to notice, is the occurrence of the short, devious, and thin veins, so common in limestone and other strata. That these small calcareous sparry veins in limestone strata, may have been the result of a disturbance in the electrical equilibrium of the limestone in its progress of consolidation, is at least highly probable, and easily comprehended. And in no way can the crystalline and sparry texture of veniform masses, enveloped in rocks, be so satisfactorily explained as from electro-molecular action.

Another fact worthy of notice is the broken, twisted, expanded, and bulged condition of the strata in particular parts, more especially the coal strata.

This condition of the coal and accompanying strata, is, I believe, generally called by colliers a shake, or broken. This shake is not an actual breach or separation in the strata, but a kind of lineal space, of more or less width, in which the coal and other strata are in a bruized, expanded, and bulged state, and having the strata close to it frequently tilted out of their regular position. Another form of this shake is, that, for a limited circular space, the strata are in a twisted, broken, and mingled condition. In both these shakes, the condition of the strata in general very much resembles the effect produced in a piece of rather dry clay, through which an electrical discharge has been sent. Then,

since the lineal shake may be called a kind of imperfect fissuriferous vein, so may the circular shake be called a kind of imperfect disruptive pipe vein.

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## SECTION III.

### ON THE REPLETION, OR FORMATION OF THE CONTENTS OF MINERAL VEINS.

Having, in the two preceding sections, explained the mechanical structure and formation of the spaces which the contents of veins occupy, the next subject of inquiry is, by what agency and *modus operandi* the repletion, or formation of the contents of veins has been effected.

The contents of veins may be divided into two classes, the *Transmutive* and the *Foreign*.

The first includes riders, douks, and other substances, which appear to have been formed from the rocks formerly occupying the place where they are found, by a process of decomposition, or impregnation.

The second includes clays, spars, metallic ores, and substances, the appearance of which denotes them to be the result of subsequent mechanical and chemical deposition.

First, of the transmutive contents of veins, riders, douks, &c.

By the term rider, is to be understood a part of the rock forming the sides or walls of veins; the nature and appearance of which have been changed in consequence of its oxidation, and impregnation with some metallic oxide, or salt, or other substance, whereby both its colour and induration are rendered more or less different from that of the rock in its native state. The metal with which the rocks forming the walls of veins are most frequently impregnated, is the oxide and different salts of iron; occasionally, however, a rider impregnated with zinc is found where that metal prevails. There are four different kinds of riders, the grey, the brown, the black, and the red, which difference of colour is probably owing to a difference in the oxidation of the iron, &c. The rocks most susceptible of being converted into riders, are those of a calcareous character; next to them are the siliceous, and least of all, those of an argillaceous nature. In general, the dark grey rider is the hardest, viz., when the rock is impregnated with the silicate of iron; next to it in hardness is the brown rider, when it is impregnated with oxide or salts of zinc; then the black, when it is impregnated with the black oxide of iron; the red always being the softest, is formed by the rocks being impregnated with the red oxide or carbonate of iron.

By the term douks, is to be understood a part of the rock, forming the walls or sides of veins, which has been changed in its nature and appearance from

decomposition, and is in such a soft state as will form a paste with water, without having to be pounded; therefore the douks will have various colours and character, according to the kind of rock of which they are formed; and the elements abstracted from it, which are generally siliceous. The rocks most susceptible of such decomposition, or of being converted into douk, are those whose base is of an argillaceous nature.

Second, of the Foreign Contents of Veins, Clays, Spars, Metallic Ores, &c.

By the term clay, is to be understood all those soft pasty substances which are the result of mechanical deposition; of course this soil will differ in its character according to the nature of the deposition, &c.

By the term spar, is to be understood all those earthy and alkaline mineral substances which assume some regular determined figure, and have a crystalline texture. These mineral substances are very numerous; the most common are quartz, calcareous and fluor spar; the external characters of which are generally so well known, as to need no particular description in this place.

By the term ore, is to be understood metals in a state of union with sulphur, carbon, oxygen, &c., which assume in general some regular figure, and have also a crystalline texture.

There are not any mineral substances that exclusively belong to any particular species of vein, they being found indifferently in all.

It has already been shewn, that a discharge of electricity is the most rational mode of accounting for the phenomena which the spaces occupied by the contents of veins present, in regard to their mechanical structure, &c. It will now be assumed that electricity, in its galvanic form, is the agent employed by nature in effecting the changes in the rocks by which the *transmutive* contents of veins are formed, and also that by which the *foreign* contents have been selected, carried to, and arranged in those spaces; and the same systematic mode of proof will be employed as in the former case.

The first fact assumed to account for the repletion of mineral veins, is, that the electric fluid pervades and penetrates the earth, more particularly those parts near to the surface. It is an acknowledged fact in the science of electricity, that the electric fluid is capable of moving through either the pores or actual substance of all material bodies, with greater or less facility according to their conducting powers. And the fact of the magnetic effects resulting from the experiments of Dr. Barlow, in coiling wires round an artificial sphere, and passing currents of electricity through them, being exactly similar to those of terrestrial magnetism, renders it highly probable that electrical currents do actually circulate in the different parts of the earth, more particularly in its external layers.

In what way electrical currents are generated and set in motion in the rocky substances forming the

crust of the earth, is an enquiry of great importance and difficulty; and, consequently, various opinions have been advanced on the subject, but no very clear and satisfactory explanation has been given of it—the opinion of some philosophers being, that they are generated by solar influence; others, that they proceed from the rotation of the earth on its axis: and others, that they result from a chemical action going on in the interior of the earth, more particularly near to its surface.

It being a fact that galvanic currents are generated and set in motion by combinations of various substances, besides those of a metallic nature; and as the external parts of the earth are disposed for the most part in beds, or layers of different kinds of rock, piled one over another; it is therefore assumed, that under this condition of its surface, the strata will form a galvanic pile or battery, giving rise to various local accumulations, and currents of electricity, the energy of which will depend on the nature and superposition of the strata, and the conducting power of the medium uniting the poles of the battery.

The order of superposition of the strata in Alston Moor and neighbourhood, being, with few exceptions, exactly similar to the arrangement of the elements in the galvanic pile of Volta, a section of this district, as the strata actually occur, is given in Plate 6. In this section, the hazles or siliceous strata may be taken to represent the

wetted card; the limestone or calcareous and coaly strata the plate of one metal; the plate beds or argillaceous strata the other plate of metal; and the water or other conducting substances filling the fissures, the uniting wire by which the circuit is completed. The electrical currents, in circulating through the strata, will take their route through the fissures; as, immediately on their formation, they would, at least near the surface, be filled with water, which is a much better conductor of electricity than the strata. And it being a general law when the electric equilibrum is disturbed, and there are open for the fluid several different routes, that it always takes the best conductors, although the course through them be more circuitous.

Therefore, from the positive pole, or strata which are in a positive electrical state, there will be a current of electricity flowing from them into the fissure; and from the fissure into the negative strata or pole. Hence, wherever chemical decomposition is the result of the currents thus generated, and circulating through the strata and in the fissures traversing them, the elements in union with the currents will be deposited in such open parts of the fissure as are in accordance with the peculiar law of their relative electrical states.

In referring the spaces which the contents of veins occupy to perforations, fissures, &c., it is to be borne in mind that, in their original condition of perforations and fissures, as in Plate 6, they were

mere fractures; and that their present size, and the condition of the rocks forming their walls, are the result of the electric power communicated to the walls at their formation, from the rocks being forcibly and suddenly torn asunder, and the electrical currents subsequently circulating in them, the effects of which would be the disintegnation, decomposition, or impregnation of the walls.

The objection brought against the idea of veins having been perforations, fissures, &c., however narrow they might be at their formation, from the impossibility of such perforations and fissures being kept open, may be answered by the fact that the strata, particularly the harder, are divided by joints or cutters into a multitude of blocks, and that in many cases, the joints or cutters are found quite as large in width as the original size of veins appears to have been where there has been no mechanical or chemical change effected in their walls. Those joints or cutters are always either empty, or only filled with a soft clay, which can be of no service as a support to their sides. It is also a fact, that veins appear only to have remained open in those strata, or parts of them, in which they have an erect position; while in those strata or parts in which they have a great slope, or hade, the sides are always found to be in contact.

It is not a necessary condition of the theory here advanced for the repletion of veins, that the spaces which their contents occupy were, in their primitive

state, of the size in which they are now found; but that they were in their primary state fractures, in which the separated parts have not been re-united or healed up, whether the walls were in contact or not; nor that they have, subsequently to their formation, been opened by any slow and progressive mechanical force to their present size, but their enlargement, and the changes which the rocks forming their walls have undergone, are the result of electro-chemical agency.

From whence the metals and other substances filling veins were originally derived, is, like all enquiries into the origin of things, inexplicable. But as the metallic ores occur disseminated in many rocks, particularly in those at a considerable depth below the surface, it is highly probable that the immediate source from which they are conveyed into the veins is the rocks in the substance of which they exist, either mechanically mixed or chemically combined. That the intermediate sources from which the metallic ores, &c. filling veins are derived, are the enclosing rocks, is to be inferred from the fact, that when veins traverse an alternating series of strata, the strata forming the sides of veins, in many cases, both above and below a stratum in which they have been found productive, appear to have always been in close contact, so as to prevent their having been filled, either by infilteration from above, or by injection from below. It is also further to be inferred, from the fact of

strata in which veins are productive alternating with those in which they are completely barren—they being generally productive in the strata in which they have an erect position, and barren in those in which they have a great inclination or hade: therefore the contents of veins are either derived from, or very intimately connected with, the nature of the rocks which they traverse.

Since every known substance, either aeriform, liquid, or solid, can be reduced in bulk by pressure, it follows, that the particles or atoms of all bodies are not in actual contact, but are separated by pores or interstices, of greater or less size according to the state in which they exist; then, as the particles, even of solid bodies, are not in actual contact, it is conceived that their pores, or the interstices, must be filled up with some highly elastic fluid (as caloric, or electricity, or both); for it is inconceivable how the molecules of matter can act upon each other without some medium of communication to connect them together.

From the mobility of gases and liquids, we are prepared to admit of their particles changing their relative positions among themselves, and situations in space; their molecules being in perpetual motion among themselves, not only from impressed forces, but also from their ever-varying state as to temperature and electrical condition. But it is not so easily to be conceived, that the like motions should be induced among the molecules of solid substances

by these agencies, where the particles appear (to the senses) to be absolutely fixed; yet as the particles of solids are not in actual contact, it must be admitted that even the molecules of solid subtances must be ever changing their relative positions among themselves, and also their situation in space when operated on by forces such as those above stated, possessing a greater intensity.

It is found in all subterraneous operations (as mining) where the rocks in which excavations are made are soft, but so tenacious as not to crush, that the excavations diminish very rapidly in size, so as to become a measureable quantity in a short time, and that even the hardest rocks through which subterraneous operations have been carried, are found to diminish in size in long periods of time. Now this gradual diminution in the size of excavations made in rocks, cannot take place except through an intestine motion among the particles of the rocks, changing not only their relative positions, but also their situations in space. The extent to which this motion in the particles of the rocks may be communicated, it would be difficult to assign limits to.

Heat appears to have great influence in modifying the arrangement of the particles of solid bodies as it in many instances dissolves the existing arrangement of the particles, and gives to them a new one, without destroying the integrity of the bodies as a whole. It is "found that prismatic

crystals of sulphate of nickel, exposed to a summer's sun in a close vessel, had their internal structure so completely altered without any external change, that when broken open, they were composed internally of octahedrons with square bases. Now the original aggregation of the internal particles had been dissolved, and a disposition given to arrange themselves in a crystalline form."* Crystals of sulphate of magnesia and sulphate of zinc, gradually heated in alcohol till it boils, lose their transparency by degrees, and when opened are found to consist of innumerable minute crystals, totally different in form from the whole crystals; and prismatic crystals of zinc are changed in a few seconds into octahedrons by the heat of the sun. Other instances might be given of the influence of even moderate changes of temperature in modifying molecular attraction in the interior of substances.

That the contents of veins and other mineral substances can be dissolved and transferred, may be inferred from the fact of substances being found in the moulds, and taking the form of the moulds whose crystallization is different to that of the substance of the models. There are many instances where the first-formed substance on the sides of the vein is fluate of lime, and the second quartz, and hence this second formation at its base, taking the form of crystallization of the first, or fluor spar, and *vice*

* Connexion of the Physical Sciences, by M. Somerville.

*versa.* That where the spaces which the crystals of the first formation had occupied are found empty, and in others either partially or entirely filled with a third substance, having the form of the mould of the first, or removed substance, points out clearly the dissolution and transference of mineral substances. Then, as we meet with cavities having a peculiar form in veins, but empty, and know that bodies having the form of these cavities do exist in the vicinity where the cavities are found, we naturally infer that the cavities are the result of these models; but when it is considered that specimens are frequently found having exactly the same formation, but from which the model has not been removed, the inference is established beyond doubt. The dissolution and transference of material atoms is further proved from the various casts of animal and vegetable remains found in the rocks from which the animal and vegetable matter has been removed, and its place supplied by mineral matter.

It has been proved by innumerable experiments on bodies, both in solution and fusion, that the chemical affinity is only a consequence of the electric condition of the particles, or atoms of bodies, and that their composition and decomposition are the result of electrical agency.

Therefore, it is highly probable that no portion of inorganic matter is in a perfect state of rest, but that its molecules are not only perpetually in motion among themselves, but are constantly chang-

ing their situations in space; which perpetual molecular motion in matter, presents to us the constitution of solid bodies quite in a new light; even the particles in them obeying the various laws of chemical affinity, electical attraction, polar concretion, &c. The immediate tendency of these chemical, electrical, and polar forces, is to occasion like particles to separate from the general mass, and to group together in more homogenous portions, such as regular crystalline masses, definite layers, nodular concretions, &c., assuming it as admitted that the strata, in consequence of their order of superposition, form a galvanic pile or battery, in which there is a development of electricity, the currents of which traverse the fissures which cut through the rocks, and that mineral substances can be disolved, transferred, and recombined in various ways by electrical agency. I shall now proceed, from these data, to explain the mode in which the repletion of veins has been effected.

It is not to be inferred, from what has been above stated, that the electric action is continued through a whole series of alternating strata; for it may be confined to a small number of them. And I am strongly persuaded, from many observations on the conditions of veins in different strata, that in many cases certain classes of strata, and the parts of the fissures contained in them, have exclusively their own electrical conditions and currents circulating in them.

It is a well attested fact, that the surfaces of substances in general, from which electricity is evolved, or is positive, have their attraction of aggregation destroyed, or are chemically dissolved, as is the case with the zinc in our common batteries. It is also a well-attested fact, that the surfaces of substances in general into which electricity is entering, or is negative, are precipitating and aggregating surfaces, as is the case with the copper in our common batteries; not even the most solid aggregates, nor firmest compound bodies, being capable of resisting the dissolving action of a current of electricity. Its operation may be slow, but the results are certain; and sooner or later, all compound bodies are, by its agency, resolved into their elemental form.

That veins possess some peculiar power in determining to, and retaining the metals, spars, &c., filling them, may be inferred from the fact, that the joints, or cutters of the strata, never contain any of the vein substances, even when they are open, and directly communicate with the veins. Had not the veins possessed some attractive action for, and restraint over, the substances filling them, we should certainly have met with some instance of the vein matter being deposited in the cracks or joints by which the strata are divided into blocks. Nor can it be said that these joints, &c. have been formed subsequently to the formation and filling up of the veins, as the nature and quantity of the contents

of veins are in many instances greatly modified by the joints, &c., at their junction with the veins; while in some cases they pass straight through the veins, without suffering any interruption.

In case any stratum, or class of strata, which a fissure traverses, is in a positive electrical state, or evolving electricity, and a contiguous stratum or class of strata is in a negative state, or absorbing electricity, and the fissure traversing them be filled with water or other conducting medium; then, whenever electro-chemical action is in operation, the elements separated from the strata forming the positive walls of the fissure will be carried into that part of it in which the enclosing strata forming the walls are negative, and there deposited, and *viceversa;* then, as has been already observed, the plate beds being generally positive in regard to the sandstones, and the sandstones positive in regard to the limestones, hence the currents in general will be from both the plate beds and sandstones towards the limestones, and from the plate beds towards the sandstones singly; which direction of the currents, as a consequence of theory, is in exact accordance with the phenomena presented by the walls of veins in these strata; the walls of veins in the plate beds being generally in a decomposed or douky state; the walls in the sandstones exhibiting the mixed conditions of impregnation and decomposition; and the walls in the limestones most generally presenting the condition of impregnation alone.

As the plates or shales generally have disseminated in them both iron and zinc, a portion of them will be eliminated; and when they are in solution, will be strongly determined to the negative pole or rock; hence the reason of the walls of veins in the limestones being in general impregnated with these salts, or converted into riders; the walls of veins in the sandstones being occasionally the same.

And as the metals in general are found disseminated in the rocks, and when in solution are electro-positive, they will be determined to the negative rocks, and there precipitated, together with such other substances as may be eliminated along with them. In case the rock be highly electro-negative, the walls of the vein will be much ridered, and the metals, &c. more or less blended or disseminated in the rider: but if the rock be only moderately electro-negative, the walls will only be in a slightly ridered state, and the metals, &c. precipitated, adhering to them in plates or ribs.

If one side of a fissure in any stratum be in a positive electrical state, or evolving electricity, and the other negative, or absorbing electricity, and the fissure be filled with a fluid, as water, with which the upper strata usually abound, then this arrangement is exactly similar to the simple galvanic circle, in which case chemical action would be brought into play. Should the water, &c. filling the fissure, hold alkaline, earthy, or metalic salt in solution, the solution would be decomposed, and the metal, &c.,

precipitated on the negative wall, and the oxygen, &c. on the positive.

With regard to the depth to which the walls of veins are changed in their nature from the enclosing rocks, it may be said generally to be from three to four feet, and very rarely to exceed ten. In the primary rocks the changes produced in the walls of veins appear to extend to greater depths into the rocks than in the secondary strata; and where they are decomposed, the matter eliminated is generally the siliceous, the argill being reduced to douk, or clay.

In order to illustrate, in as clear a manner as the complicated nature of the subject will admit, the seemingly-capricious disposition of the contents of veins, as presented to us in the operations of mining, I shall state a few general laws of electrical action by which the phenomena may be explained.

First. That bodies electrified, either positively or negatively, repel those in the same electrical state, and attract those in the opposite electrical state.

Second. That bodies either in a positive or negative electrical state, attract those in a neutral state, by the law of induction.

Third. That bodies in a highly-active electrical state, whether positive or negative, attract very small bodies, or the atoms of bodies, when in the vicinity of the highly-active electrified body, which are in the same electrical state, by the law of induction.

Then, as oxygen, chlorine, iodine, and fluorine, and the substances in which their properties predominate, are naturally in a negative electrical state, they will be attracted by positively electrified bodies, and repelled by those which are negatively electrified.

And as the metals, and all other substances in their elementary state, are naturally in a positive electrical state, they will be attracted by negatively electrified bodies, and repelled by those positively electrified; but small bodies, or atoms of bodies, are attracted by large bodies in the same electrical state as themselves.

From the above principles and laws of electrical action, may be explained, in a clear and rational manner, not only the intersection and arrangement of veins, but also the sudden and apparently capricious changes that occur in their nature and disposition. For instance, suppose the rock forming the walls of a vein to be electrified negatively, in this case they will attract to them the electro-positive elements of matter, as the metals, &c.; but when these electro-positive elements are accumulated on the walls to some certain thickness, the action of the rock will become null, and the positively polarized substances planting the walls will act as electro-positive surfaces, and attract to them, or polarize, the electro-negative elements, as oxygen, fluorine, &c., or substances in which they predominate, as quartz, fluate of lime, &c.; these alternations being

repeated till the vein is filled up, if the electrical action continue.

Again, if the rock forming the walls of a vein be positively electrified, it will attract, or polarize, the electro-negative substances, as quartz, fluate of lime, &c., and when these substances are accumulated on the walls to some certain thickness, they will become the polarizing surfaces, and will attract to them, or polarize, the electro-positive substances, as the metals, &c.; these alternations being repeated in the inverse order to the former till the vein is filled up, if the electrical action is continued.

If, at the same time, one part or point in a vein be in an electro-negative state, while another is in an electro-positive state (which is no uncommon condition with simple substances), the one part will be attracting to it matter of a different nature to that of the other; and in case these alternate positive and negative states of the vein are only separated by very short intervals, the contents of it must be disposed in a very mixed state, and present a seemingly capricious arrangement—if arrangement it can be called at all, in the ordinary acceptation of the word; yet the position of each particle is the result of the same definite agency as that by which the most exact chemical effects are produced.

This law of differently electrified surfaces, or points, in collecting on them oppositely electrified particles, or atoms of bodies, is very elegantly and

clearly illustrated by an experiment devised by Professor Lichtenberg.

With the knob of a jar charged with positive electricity, trace on the surface of a smooth plate of glass, or any resinous substance, various lines, at pleasure ; then, with the knob of a jar charged negatively, draw several other lines in the same way, and set the plate vertically on its edge ; by the friction, &c., produced by triturating red lead and sulphur together in a mortar, the red lead is rendered positive and the sulphur negative; then, if the powder be projected in its mixed state against the plate by a powder puff, or blown from the barrel of a quill, the sulphur will attach itself to the positively electrified lines, and the red lead to those negatively electrified, forming a series of yellow and red lines: there not being a particle of red lead attached to the positively electrified lines, nor of sulphur to those negatively electrified.

When the ore contained in a vein is scattered through the vein substance in nodular masses, I am fully persuaded, from the most attentive observation, that this disposition of the ore in many cases is the result of a concretionary action or coalition of minute particles previously disseminated through the vein substance.

If it be admitted, as a principle in the repletion of veins, that all the mineral substances which constitute them, were originally disseminated through, and immediately derived from, the enclosing rocks, then,

in this case, veins ought to be of the greatest magnitude, and most productive, at or near those points in which they cross each other, and also where there are a number of parallel contiguous veins, with small veins or strings falling into them from either side or both; which consequence of theory is in exact accordance with fact.

It being conceived that the earth derives its magnetism from electrical currents circulating in it, in a direction at right angles to the magnetic meridian, they will, in some cases, concur with the local currents of the strata, and in others be antagonist to them; from which concurrence or antagonism of the currents will result a variation in the internal condition of veins.

In conclusion, it may be stated, that the electric currents will have their routes through the veins in various directions. In case they have a horizontal set, their route will be from and towards all points of the compass; when they have a vertical set, their route will sometimes be from below upwards, but as the deep strata are in general negative in regard to the upper, the positive current will generally have a tendency downwards. It is not to be inferred from these remarks, that currents of electricity traverse each fissure or vein throughout its whole extent in length and depth, but that their generation and circulation are local, and not the result of any general, but special conditions in the strata.

# SECTION IV.

## ON THE PHENOMENA OF THE INTERSECTION OF VEINS, AND THEIR RELATIVE AGES.

Having, in the first section of this work, explained the mechanical structure of veins; and in the second, from these data, traced the formation of the spaces which contain the substances that constitute veins to a discharge of electricity, or to electricity in its coerced form; and, in the third, traced the filling up, or repletion of these spaces to electro-chemical agency, or to electricity in its free or galvanized form; it is now intended, in the present section, to trace up, and explain from electro-dynamics, or the action of one current of electricity on another, the phenomena which veins present at their intersection; and to determine their relative ages.

The correctness of the hypothesis here advanced to explain the phenomena of the intersection of veins, &c. must depend on, and be judged by, the agreement between the principles of the science of electro-dynamics; as likewise, the agreement between the theoretical deductions involving them,

and the actual phenomena which veins present to us in traversing one another, &c.

In no department of geology have the causes assigned by geologists, for the explanation of any particular class of phenomena, appeared to me to be so inadequate to it, as those proposed to explain the phenomena of the traversion of veins, and their relative ages; nor in any are the facts more mis-stated, or the deductions more incorrect.

The principles in the science of electro-dynamics on which it is proposed here to explain the phenomena of the traversion of veins, &c. are, that when two electrical currents are inclined to each other at any angle, they are always naturally repulsive when one of them approaches to, and the other recedes from, the summit of the angle, or point of intersection or coalescence. That, on the contrary, they mutually attract each other when they both approach to, or both recede from, the summit of the angle, or point of intersection or coalescence. And that the intensity of the action of each current on the other, is inversely as the square of the distance, and is exerted in a direction perpendicular to their routes.

It has been shown in the last section that currents of electricity traverse veins in all directions. That when the set of the current is longitudinally through the vein, it may pass in either direction through it; for instance, if a vein have an east and west course or bearing, the current (positive)

may have its routes through the vein either from east to west, or from west to east; and when the set of the currents is vertically through the vein, it may be either from below upwards, or from above downwards.

Then, in order to render the application of electro-dynamic action to the explanation of the phenomena of the traversion of veins, &c., as intelligible as the complicated nature of the subject will admit; let A B, Plate 8, Fig. 49, be the longitudinal course of a prior formed fissure or vein having a current (positive) of electricity moving through it from A to B, or from right to left; and let C G H be a posterior formed vein, the discharge or coerced current by which it was formed having its origin in the point C, and its uninterrupted course being C G H. Then, since the current of electricity passing through the prior formed vein A B, is either hydro or hermo-electric, it will be a continuous current, and that of the discharged or coerced current originating at C, being a sudden electrical irruption, it will be a discontinuous current. Hence the discharge, or coerced current C, in its route from C to G, will be situated wholly on the one side of the continuous current A B, and in its course from G to H it will be wholly situated on the contrary side of the continuous current A B. Therefore the effect produced by a prior formed vein, or one of posterior formation, will be similar to the effect that a fixed

extended electrical current produces on an unstaid terminated current. Hence, according to the hypothesis here advanced to explain the phenomena which veins present to us at their intersection, the supposition that all veins were not formed at the very same instant of absolute time, must agree in all details with the electro-dynamic effects of a fixed extended electrical current on an unstaid terminated current. Then, in Fig. 49, let A G and B G be made equal to each other, let there be drawn A C and B C, and let the direction of the current moving in the fixed channel of the prior formed vein be from A to B. Then, since the part of the continuous fixed current moving in the prior formed vein A B from A to G, and the part of the discontinuous unstaid current of formation of the posterior vein C H, from C to G, are both approaching to the summit of the angle, or point G of intersection or coalescence of the veins; hence, agreeably to the law of electro-dynamics expressed at page 54, they will attract each other, which attractive action let C *w* represent. But, as the part of the continuous fixed current moving in the prior formed vein A B from G to B, is receding from the summit of the angle, or point of intersection or coalescence; and that of the current C, from C to G, is approaching to it, they will repel one another; which repulsion let C *x* represent. Then let *w z* and *x z* be drawn parallel to C *x* and C *w*, and then draw C *z*, which will be

the resultant of the attractive and repulsive action of the continuous fixed current moving in the prior formed vein A B, or the discontinuous unstaid current of formation of the posterior vein from C to G, which is perpendicular to the course of the vein, according to the law of electro-dynamics expressed in page 54.

Then, let there be drawn parallel to C *z* the several arrows, 1, 2, 3, 4, 5, &c., which will represent the direction of the force exerted by the continuous fixed current moving in the prior formed vein from A to B, or the discontinuous unstaid current of formation of the posterior vein from C to G. Hence, the posterior, or traversed vein on the side C G, will, at and near to the point of intersection or coalescence, be more or less deflected and drawn along the channel of the prior formed, or traversing vein, in a direction contrary to that in which the current is flowing in at M towards A; and it will intersect or be found at the point N instead of at G, in the traversing vein, and either pass straight through from N to P, or continue to follow the course of the traversing vein before leaving it, to some point, M, according to the intensity of the discharge at C.

Then, as regards the effect of the prior formed or traversing vein, or the posterior or traversed vein, on its leaving the traversing vein on the other side, G H. We have in this case, according to the law of action in electro-dynamics, the current A M or

A P approaching to the point of intersection, or coalescence of the veins, and the current M D or P D receding from that point; hence the action of the fixed continuous current A M or A P on the unstaid discontinuous current M D or P D will be repulsive, which repulsion let H $x'$ represent. Then, since the current M B or P B is receding from the point of intersection of the veins, and also as the current M D′ or P D is also receding from the point of intersection, the action of the fixed continuous current M B or P B on the unstaid discontinuous current M D′ or P D will be attractive, which attraction let H $w'$ represent. Then let there be drawn $w'$ $z'$ and $x'$ $z'$ parallel to H $x'$ and H $w'$; and also draw H $z$, then will H $z$ be the resultant of the repulsive and attractive action of the fixed continuous current moving in the prior formed vein A B, from A to B; on the unstaid discontinuous current M D or P D from M to D′ or P to D, which is perpendicular to both, to the original and deflected course of the vein G H and M D or P D* which is agreeable to the law of electro-dynamics. Page 54.

Then let there be drawn parallel to H $z'$ the several arrows 10, 11, 12, 13, &c., which will represent the direction of the power exerted by the fixed continuous current in the prior formed vein

* The original course of the vein has been used in the diagram instead of the deflected one, for the purpose of uniformity, as the result is exactly the same.

A B, on the unstaid discontinuous current C in its route of formation of the posterior vein, from M to D′ or P to D. Therefore the posterior or traversed vein, on the side G H of the traversing vein, will, at or near its point of intersection with it, be deflected or curved in the direction in which the current in the prior formed vein is flowing, viz. towards B, as represented at V.

A popular, but very apt, illustration of the influence which an electrical current passing along a prior formed vein longitudinally on the current of formation of a posterior vein, may be conceived by imagining the path or tract of a block of wood, or other light body, being projected along the surface of smooth water, obliquely to its banks, with great rapidity, and at the same time having a rope attached to it of which a person has hold, and so placed on the opposite bank as always to be at right angles to its projection, hauling or pulling the block towards him.

This species of deflection in veins (or shift as it is generally called) being in the direction of the acute angles of the intersection of the veins; therefore it may be called an acuteangled deflection (or shift).

Now, let the electrical current in the prior formed vein, instead of moving from A to B or from right to left, move from B to A or from left to right, as represented in Fig. 50. And let the discharge C, or current of formation of the posterior vein be the

same as in the last case from C to H. Then as has been demonstrated in the preceding case, Fig. 49*, C *s* will be the attractive action of the parts of the continuous currrent B G of the prior formed vein, on the part C G of the unstaid discontinuous current C in its route from C to G. And also will C P be the repulsive action of the part of the fixed continuous current of the prior formed vein G A, or the unstaid discontinuous current C, in its route from C to G. Then let *p v* and *s v* be drawn parallel to B C and A C, and join C *v*, so will C *v* be the resultant of the attractive and repulsive action of the fixed continuous current moving in the prior formed vein from B to A, or the unstaid discontinuous current C in its route from C to G.

Then if there be drawn parallel to C *v* the several arrows 15, 16, 17, 18, &c., which will represent the direction of the force exerted by the continuous fixed current moving from B to A, or the unstaid discontinuous current C in its route of formation of the posterior vein from C to G. Hence it will be deflected, or take the channel of the prior formed vein, in a direction contrary to the flowing of the current, viz., towards B. And it will intersect the

* It is only intended to give the results of the electro-dynamic action of the fixed continuous current moving in the prior formed vein, or the unstaid discontinuous current of formation of the posterior vein, in the succeeding cases, the same chain of reasoning applying to all the cases.

prior formed vein at O instead of at G, and either pass straight through from O to R, or take the course of the traversing or prior formed vein for a geater or less distance, as to S, according to the intensity of the discharge at C.

Then as regards the action of the current B A in the prior formed vein, or the current of formation of the posterior vein in its route from R to E′ or S to E; we have in this case H $p'$ its repulsive action, and H $s'$ its attractive action, and H $v'$ the resultant of these repulsive and attractive actions.

Then if there be drawn parallel to N $v$ the several arrows, 21, 22, 23, 24, &c., they will represent the direction of the force exerted by the continuous fixed current of the prior formed vein moving from B to A, or the unstaid discontinuous current C, in its route from R to E or S to E′. So shall the posterior vein on its receding side R E or S E of the prior formed or traversing vein near to its intersection with it, be more or less bent in the direction in which the current of the prior formed or traversing vein is flowing, as at $v$ and V′. This species of deflection in veins (or shift, as it is commonly called) being in the direction of the obtuse angle of intersection of the veins, therefore it may be called an obtuse-angled deflection (or shift).

In the preceding popular illustration, the person who was supposed to be hauling the block to him was placed on the opposite bank from which the block was projected, and hence giving to it a more

direct course to the bank. But in this case, the person is placed on the same bank from which the block is projected obliquely to the banks, and hence dragging it to the said bank, thereby increasing the obliquity of its course to the bank, from which cause, combined with the obliquity of the projection, the deflection may become so great as that the path of the block may coincide with the channel of the water; hence, a posterior formed vein under these conditions may, at its junction with a prior formed vein, be so much deflected, that its course may coincide with the course of the prior formed vein, or deviate so slightly from it as to continue embodied with the prior formed vein, from such a distance as to set aside all identity of parts on the opposite sides of the prior formed or traversing vein.

When the current of formation of a posterior vein, at its junction with a prior formed vein, unites with this current of the prior formed vein instead of passing through it, in mining language the posterior vein is said to be cut out, or off, by the prior formed vein.

When the course of the posterior vein is at right angles to the course of the prior formed veins, as in Fig. 51, then, as has been demonstrated in the case Fig. 49, we will have C N P D, or C N M D', the course of the posterior vein, instead of the straight course C G H, when the current in the prior formed vein is moving from A to B, or from right

to left; but when the current in the prior formed vein is moving from B to A, or from left to right, Fig. 52, the course of the posterior vein will be C O R E, or C O S E, as has been demonstrated in the case Fig. 50. The action of the fixed continuous current moving in the prior formed vein on the current of formation of the posterior vein on the side C N, or when approaching to the point of intersection, is in a direction contrary to the motion of the current moving in the prior formed vein A B, viz., towards the right, as shown by the arrows 1, 2, 3, 4, 5, &c., which are parallel to C Z, the resultant of the attractive and repulsive action of A B or C G; but when the current in the prior formed vein is moving from B to A, its action on the current of formation of the posterior vein on the side approaching the point of intersection will be towards the left, as is shown by the arrows 15, 16, 17, 18, &c., which are parallel to C V, the resultant of the attractive and repulsive action of B A or C G.

The action of the fixed continuous current, moving in the prior formed vein, on the current of formation of the posterior vein, in receding from the point of intersection, or on the side G H, when the current in its moving from A to B will be in the direction in which the current is flowing, as shown by the arrows 10, 11, 12, 13, 14, &c., Fig. 51, which are parallel to H Z, the resultant of the repulsive and attractive action of A B, or P D, or M D′, which will be bent at or near to the points P and M

inwards to the original course G H; and the arrows 21, 22, 23, 24, &c., Fig. 52, which are parallel to H V′, the resultant of the repulsive and attractive action of B A, when the current is moving from B to A, or R E, or S E, which is also inwards to the original course H G.

Should the prior formed vein A B, fig. 53, have no electrical current traversing it at the place which the current of formation of the posterior veins intersects it, then will the current of formation of the posterior vein pass straight through the prior formed vein, as shewn in Fig. 53, without interruption, let the angle of intersection be what it may.

In Fig. 55, let A G B be the vertical course of the prior formed vein underlying to the right; and C G H the vertical course of a posterior vein underlying the same way, but with a much greater inclination.

Should the current traversing the prior formed vein have a downward set, and the current of formation of the posterior vein be also downwards, then will the fixed continuous current of the prior formed vein draw to it the current of the formation of the posterior vein so as to meet it at the point O instead of the point G, and will be deflected for a greater or less distance, as to S, and thence proceed to E, the deflection O S being what is called the upheave. The effect will be the same when the veins underlie in opposite directions.

But should the current traversing the prior

formed vein have an upward set, as in Fig. 56, and the current of formation of the posterior vein a downward set; then will the fixed continuous current of the prior formed vein push from it the current of formation of the posterior vein, so as not to meet it at the point G, but at the point O, and then take the course of the prior formed vein from O to S, and from thence to E; the deflection O S being what is called a down-heave. The effect will be the same if the veins underlie in contrary directions.

Therefore the phenomena which veins present at their intersections may be explained in a clear and satisfactory way, even in their most minute details, from the action of a fixed, extended, or continuous electrical current, or an unstaid terminated or discontinuous current. And all the theoretical conclusions deduced from the hypothesis are in exact accordance with the phenomena disclosed to us in mining.

I am aware that in this hypothesis it is the posterior formed vein which is made the deflected or shifted vein; whereas all Geologists who have noticed the subject (so far as I know) have inferred that the shift belongs to the prior formed vein, which has had its corresponding parts displaced by the movement which the rocks underwent at the formation of the posterior formed vein. But this view of the production of the displacement or shift is singularly unhappy, as it is in effect

asserting that the cause is a consequence of the effect.

It is quite impossible to explain the *fact* of two prior formed veins in the vicinity of each other, and which both underlie the same way, Fig. 54, being shifted to different distances, in contrary directions, from any movement impressed on the rock, either sideways, downwards, or upwards. For whatever movement the rock may have had impressed on it, on the opposite sides of the posterior vein, at its formation, the prior formed veins must have both been moved in the same direction, and retain their relative distance on each side to one another.

Nor can the *fact* of the union, or splitting of a prior formed vein be explained by a posterior vein cutting it in two; or the *fact* of a prior formed vein changing its throw, or tilting down different sides on the contrary sides of a posterior vein by its being cut in two by the more recent formed vein; with a number of others which the limits of this work will not admit of being noticed; but all of which facts can be explained in the most clear and satisfactory manner by electro-dynamics.

Since all prior formed veins, which have not a vertical position, but are inclined to the horizon; which are cut through by a posterior formed vein, which at its formation was accompanied with an elevation or depression of one side, must be removed out of their downward course, according to their inclination, and the elevation or depression of

the rock accompanying the formation of the posterior formed vein;

The effects resulting from a depression or elevation of the strata in displacing the downward course of a prior formed vein according to its position to the horizon, may be observed and studied in Figs. 57, 58, and 59. But since the shift of a prior formed vein from any transverse lineal elevation, or depression of the strata, is as the *tangent* of the angle which its downward course makes, with a vertical line, when the elevation or depression of the line is made radius. And as veins in general have a tolerably erect position, and the throw or difference of level of the strata on the opposite sides of them is generally only small, the effect of a posterior formed vein in shifting or displacing a prior formed vein must, in most instances, be quite inappreciable.

The electro-dynamical hypothesis here advanced, to explain the phenomena of the intersection, and relative age of veins making the more recent formed vein the traversed or dislocated vein, and the traversing or uninterrupted vein the more ancient, which is not in unison with the generally received opinion on the subject, it may not be amiss to notice a few facts which are not connected with the electro-dynamical theory, but which corroborate the solution given by it of the relative age of veins.

It is a rule to which there are very few exceptions

that those veins which have a great and uniform inclination traverse those that have a more inflected and vertical downward course. Now it is a very natural inference to suppose that the first formed fissures would, from the more uniform and less induration of the strata, have a greater and more uniform inclination than those subsequently formed when the conditions of the strata were greatly changed.

Again, with few exceptions, these veins whose contents are of the most mechanical nature traverse those whose contents are of a more chemical character. It is also very natural to suppose, as the strata were more soft when fissures begun to be first formed in them, they would also be less distinct in their chemical characters. Hence, mechanical deposition would prevail more than that of chemical, and give to the first formed veins their sedimentary character.

Again, with few exceptions, those veins whose chemical contents are of a simple earthy or alkaline character traverse those whose contents are more compounded and metallıferous. From this fact it is very natural to suppose, as the strata approach more and more to their distinct chemical characters, their electrical action would become more intense; and hence the fissures then formed, or remaining unfilled, as the substances carried to and precipitated from them, would be more numerous, that their contents would be more various and metalliferous.

## SECTION V.

### THE APPLICATION OF THE THEORETICAL PRINCIPLES CONTAINED IN THE PRECEDING SECTIONS TO THE ART OF MINING.

Having, in the preceding sections, explained the mechanical structure, the mode of formation, the filling up, and the relative age of veins, I purpose, in the present, to apply the theoretical deductions propounded in each to the art of mining.

It is a general rule, to which there are few exceptions, that particular species of vein, and also particular parts of the same vein, are more especially filled with some particular mineral substance than others. This position being admitted, it would be desirable, for the interests of mining, if the circumstances which influence, and are indicative of the prevalence of any particular mineral substance in veins could be pointed out, more particularly those which influence, and are indicative of the prevalence of metallic substances—viz., to point out in what respects the veins that are more metalliferous differ from those whose contents are of a more earthy and alkaline nature. For any thing, how little so ever, that can be done in this respect, must be acceptable, as tending to advance the art of mining; the searching for, and the extracting of metals

from veins, constituting the profession and business of the metalliferous miners.

Veins in mining are divided into two classes, the metalliferous or quick, and the non-metalliferous or dead; and the metalliferous or quick, into two species—the rich and the poor. A rich vein being one, in which is found a considerable quantity of the ore of some metal, without any reference to the quantity of any other mineral substance it may contain. A poor vein is one in which the quantity of ore found in it is scarcely worth extracting, and has no reference to the quantity of the other mineral substances it may contain.

Therefore, the chief business or object of the application of any theory of mineral veins to the art of mining must be, to explain, from the principles of the theory, the peculiarities of those veins that are generally quick, or very fruitful, from those that are dead, or extremely barren, as fully and clearly as the complicated nature of the subject will permit.

The first remarkable fact with respect to the difference in the nature of the contents of veins, is, that those which have a north and south direction or bearing, or one slightly deviating from it, are, in general, less metalliferious or quick than those which have an east and west direction or bearing, or one slightly deviating from it. Both the mechanical and chemical contents of the north and south veins being more generally of an earthy and

alkaline nature, and having their walls in a more decomposed and disintegrated state than the east and west veins. A few other remarkable differences between the condition of the north and south and east and west veins are as follows:—First, that the longitudinal courses of the north and south running veins are in general more straight, of greater length, have fewer strings or small veins branching from them, and in general have a greater and more uniform inclination than those having an east and west direction. Second, That the north and south veins present in their walls a more writhed, withered character, and in general traverse and shift those having an east and west direction.

Now the conclusion to which all those differences between the condition of the north and south, and east and west veins lead is, that at the time of the repletion of the north and south veins the strata were more soft, less distinct in their chemical characters, less energetic in their electrical action, and more diffused in their effects.

It has been demonstrated, in the last section, that the traversing veins are of prior formation to those traversed; and as the north and south, in general, traverse the east and west veins, therefore, the north and south veins are of prior formation to the east and west.

Hence the electrical currents circulating in the earth from east to west, to which it is supposed its magnetism is due, would pass transversely through

or cross the north and south veins in a feeble and diffused state. But after the formation of the east and west veins took place, these general currents would have a tendency to converge and form distinct streams, and take the course of the east and west veins in rotating the earth, in which concentrated condition of the general electrical currents would give full scope to the strata to develope their electric action, the result of which action would be the generation of numerous local currents in the strata; and from the electro-dynamic law, that electric currents moving the same way attract each other, the strata currents would be determined to the east, and fissures or veins rather than to those having a north and south direction.

Therefore, if all the substances constituting veins were originally disseminated in the enclosing rocks, and have been conveyed into the veins from electro-molecular action; then not only the metals, &c. contained in the rocks, but also those previously deposited in the north and south veins, would be determined towards the east and west veins.

Whence the electrical theory of veins here advanced, affords a rational and clear explanation why the east and west veins are more metalliferous than those having a north and south direction; and also, why north and south veins are always more metalliferous at and near their junction with an east and west vein, than in those parts which are distant from the coalesence.

By following out the theoretical consequences deduced already, they afford a clear and intelligible explanation why east and west veins are frequently more productive near their intersection by north and south, or cross veins; and also, where strings on small veins are falling into them from either side, than in those parts which are not so circumstanced.

In order to render these deductions complete, there is still wanting some rational explanation of the tendency of the first fissures or veins to a north and south, rather than to an east and west direction; and this can be done in the most satisfactory manner from electro-dynamics.

The earth being an oblate spheroid, and the solar influence greatest under the equator, the electro-magnetic currents rotating in it from east to west, would have the greatest intensity at the equator—then, as currents of electricity moving the same way, attract each other with a force in proportion to their intensity, the currents on each side of the equator would be attracted or determined to it in lines nearly coinciding with the terrestrial meridians. Therefore, where even an accumulation of electricity might first be formed, the discharges, in the northern hemisphere, would be from north to south, and in the southern, from south to north; the coercive force being least in these directions. After the earth's crust was thus torn into a number of thin slabs, the coersive force to the discharges

would then become least in an east and west direction; and hence, a second class of fissures or veins having a course transverse to the first formed, or in a direction from east to west. Hereafter, the fissuring of the fragments would become so complicated, that no theory could be relied on to specify any exact order of precedency of formation that would generally prevail.

Another remarkable fact, with regard to the difference in the nature of the contents of veins is, that the hard capacious vein, Fig. 40, or that which overlies the side in which the strata are on a higher level, are more metalliferous, than the soft capaceous vein, Fig. 41, or which overlie the side in which the strata are on a lower level.

The difference in mechanical structure, which distinguishes soft from hard capacious veins has never received, by miners, that attention which it ought to command, not only from the former being less metalliferous than the latter, but also from their being metaliferious in different strata.

Of the soft capacious species are, Crag Green North Vein, and Stow Crag Vein; of the hard capacious species, are the small Cleugh, the Ramgill, the Brownly Hill, the Grass Field, and the Hudgill Burn Veins, in Alston Moor.

The strata, in which theory assignsthe soft capaceous vein to be productive, are thin hard shales or plates, and thin soft sandstones immediately underlying a limestone. The strata, in which theory assigns

the hard capaceous vein to be productive, are thick beds of limestone, and sandstone immediately underlying soft shales, or plates, which is in accordance with fact.

Another remarkable fact, with respect to veins (at least in the secondary strata) is, that they are not only less metaliferous, but the ores are of poorer quality in the deep strata, than those near to the surface. That this fact has been disputed by some geologists is known, but its truth has been proved in such a vast variety of circumstances and situations, to the great loss and discomforture of the adventurers, that few, if any, practical miners, can now be induced to engage in a speculation, the object of which is a trial of a vein at a great depth below the surface, however productive it may have been in the upper strata. That there are occasionally to be found patches of metal, &c. at a great depth in veins, (generally disseminated in the enclosing rocks,) it is not intended here to question; but, in general, the quantity is so small, as not to pay the expense of extracting, independent of the increased cost of working mines at a great depth. The explanation which theory offers of this condition of veins, and the strata at a great depth below the surface, is, that the strata are highly electro-negative to the veins.

A fact, worthy of notice, respecting the useful metals is, that they belong to particular formations of rocks, some of them being indigenous to certain

rocks, while others are aliens to them. In general, gold and tin are found in the greatest quantity in granite, and the rocks immediately reposing on it; copper, in the various slate formations, which repose on the former series; lead, in the mountain limestone formation; iron, in the coal strata; and silver, in all these formations, it being in general found forming a natural alloy with the other metals, more particularly lead. Above the coal strata, not any of the metals, I believe, have been found in such quantity as to lead to any mining operations being established for their extraction.

Another condition, which has considerable influence on the productiveness of veins, is, that when a vein is quite insulated, viz. at a great distance from any other vein on either side of it, nor has falling into it any strings or small veins, (called by miners feeders) it will, in general, be unproductive. But when there are a number of parallel veins in the vicinity of each other, in general, one or more of them will be productive; also, when a vein is intersected by another at an acute angle, or another vein falls into it from either side, either one or both will generally be productive at the point of junction. The relation in which veins thus stand to each other bears a striking resemblance to the galvanic apparatus; and their being more productive when thus connected would appear to be the result of a more energetic electro-chemical action in the strata.

The prevalence and productiveness of mineral

veins appear to be very intimately connected with the proximity or junction of dissimilar rocks, where it may be supposed the electro-molecular, and electro-chemical actions are most energetic. In Cornwall, I believe, it is at or near the junction of the killas (clay slate), with the granite, or of the killas, with the elvan courses; or phorphyritic beds or dykes, that the veins are most productive. In Cumberland, Northumberland, Durham, Westmorland, Yorkshire, and Derbyshire, in consequence of the limestones and sandstones being interstratified with basalt, chert, and shale; and of the proximity of the rocks to, and having a position to the east of the primary slate formations in these districts. In Flintshire and Shropshire, in consequence of the limestones and sandstones being interstratified with shale; and of the proximity of the rocks to, and having a position in these districts to the east and north east of the primary slate formations, &c

It has been noticed before when veins traverse an alternating series of strata, that in those in which they have a great inclination, the walls are in general in close contact, and their contents are composed of the rocks in a decomposed or douky state. But in the strata in which they have an erect position, the walls are separated from each other, and the cavities thus formed are in general filled with some foreign substances.

In stratified districts, as in the north of England, the *throw* of veins, or the difference of level of the

corresponding strata on the opposite sides of them, is a matter of great importance, as it materially influences their productiveness.

In Alston Moor, and neighbouring districts, the country is chiefly composed of limestone, sandstone, plate, or shale. In the two former, the veins produce ore, but they are more productive in the limestones than in the sandstones; but in the plate beds or shales, they are in general unproductive. Hence the *throw* should not exceed three yards, so that the sides or walls of the veins should be of similar strata; viz., limestone facing limestone, and sandstone facing sandstone, and shale opposite to shale.

When the *throw* is very considerable, as the limestones and sandstones are in general not more than from four to eight fathoms in thickness, the unproductive beds are brought in opposition to those which are productive, in which case the veins are generally unproductive, the hanging wall being composed of soft shale or plate, is in a crushed and decomposed condition, and hence in contact with the limestones, &c.

Then, since the mechanical structure of the hard capacious vein, when its throw is only small, will have both its walls formed of the same strata, and also as the walls in the limestones and sandstones are more or less separated, and in the shales are in close contact, hence probably the reason why veins are more productive in the limestones and sandstones, or those strata in which they have an erect

position, than in the shales, &c., or those strata in which they are much inclined to the horizon.

When both the cheeks or walls of a vein are in a negative electrical state, there will in general be little, if any change, produced in the enclosing rocks; and if they are filled with any foreign substances, it will be either some metallic ore, or some mechanical deposition, as clay, or both in a mixed condition.

But if both the cheeks or walls of a vein are in a positive electrical state, the enclosing rocks where they are in contact will in general be in a decomposed or douky state, and where they are separated from each other, the enclosing rocks will be in a ridered state, as the substances in which oxygen, &c. prevail (as the salts of iron, &c.) are always attracted by positively electrified surfaces, and repelled by those negatively electrified; and the ore, when the vein is productive, will be disseminated or scattered through the rider forming the walls of the vein.

In most cases where the sides or cheeks of veins are in a ridered state, they present very marked differences in their appearance and character; the rider when formed by the red oxide of iron being in general, in a soft, withered, and carious condition, and having a reddish brown colour. And where it has crumbled to dust, it forms the mineral soil that so much resembles in appearance rappee snuff, which is considered by all miners as the most favourable indication of a vein being productive.

It is a fact that the contents of veins have been found in many instances to be partly or entirely mechanical, when the strata forming the cheeks or walls of veins were in such a soft and fragile state that on the smallest excavation being made in the veins, the rock would have tumbled into, and filled it up. Then, in what way, it may be asked, were the sides of veins in this case kept apart until the vein was filled? In answer to this, it may be stated, that this condition of the rock forming the walls of veins is not its natural one, but has been the result of electro-chemical action, disintegrating and decomposing the rock subsequently to the existence of the veins, as mere fractures or fissures.

That the mechanical contents of veins are in many instances the result of the disintegration and decomposition of the rocks forming their walls, by electro-chemical agency, and that they have not in all cases been introduced into them by currents of running water, may be inferred from the condition in which they are placed in some cases. There are many instances of matter having a sedimentary character, being enclosed in cavities in the flat veins to which there was no egress for the sediment, but through the solid rock; the cavities not having (sensibly) the most minute crack leading into them. Therefore it cannot be conceived that the sedimentary matter inclosed in these close cavities had been washed into them by water, but had been formed from the disintegration and decomposition of the rock forming the walls of the cavities.

When the cavities contain no loose matter, the rider forming their sides is in general in a very high state of induration ; and they have no regular form, but their appearance very much resembles the effect of a chemical solvent, on a solid differing much in its solubility ; and the foreign substances, when any, attached to the surface of the cavities are in a very perfect state of crystallization, and have a brilliant lustre. In some cases, large masses of rider, with the foreign substances on them, have been detached from the surface of the cavities, not only from the top, but also from both the bottom and sides. In other cases the detached masses are small, resembling the scales detached from hot iron in hammering it ; which scaly condition of the detachments is called by miners shiver. In this shivery condition of the cavities their internal surface in general very much resembles the leafy or scaly structure of the exterior of a wasp's nest when it is ruffled up.

The way in which these close and insulated cavities have been carved out, and the elements of the rock, either in part or entirely conveyed away, and other substances have been introduced into them, is, perhaps, not so easily comprehended as the introduction to, and filling up of, the fissuriferous vein with foreign matter ; yet their formation and repletion are equally consistent with the law and mode of action of electricity.

That electricity in motion possesses the power to

select, and a momentum to convey, the elements and finer particles of matter through masses of other matter is fully established by many experiments. For we know nothing of electricity, except as it is presented to us in connexion with matter in a solid, liquid, or uniform state. And likewise, as we have no knowledge of matter separate or apart from electricity, and as both analogy and observation lead to the conclusion that they are co-existent, therefore, if electricity be the agent employed by nature in the reduction of compound bodies to their elements, each particle of it will, in its most simple state, contain a portion of electricity. Hence, when the electrical equilibrium is disturbed, and a current of electricity is set in motion, the elements, or atoms of matter incorporated with it, will be carried to their respective polar stations, and there deposited.

It is a fact established by many experiments in electro-chemical science, that elements or atoms of one chemical or electrical quality in solution may be passed through elements or atoms of a different chemical or electrical quality without interruption, or an union taking place between them; and solid substances, as glass, sulphate of baryta, fluor spar, carbonate of lime, &c., when moistened and placed between surfaces connected with the opposite poles of a voltaic apparatus are decomposed, and their elements carried to their respective polar positions.

That metallic ores of lead, copper, and iron, in the

state of sulphurets, are disseminated through the substance of the deep strata quite apart from veins in Alston Moor, has been fully established in the instance of Nentforce level, and some other deep drivings carried through them for discovery, &c., the lead and copper ores always occurring in thin leaves or scales, and the iron in cubes.

Although the theory here advanced for the formation, filling up, &c., of mineral veins has no connexion with the transmutation of matter, or that of a contemporaneous formation of veins with the enclosing rocks, or that of a deposition of the contents of them from solution, or that of their sublimation or injection into them from below, yet it embraces in it principles that which will supply all the conditions required in the above theoretical modes of explaining the phenomena of mineral veins.

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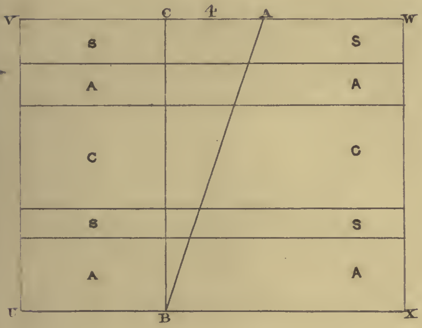
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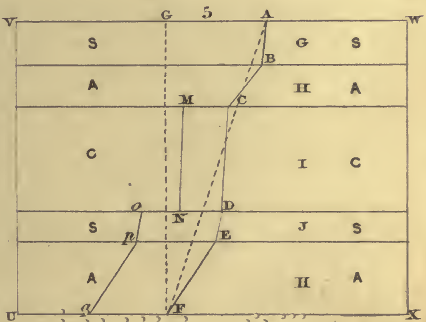
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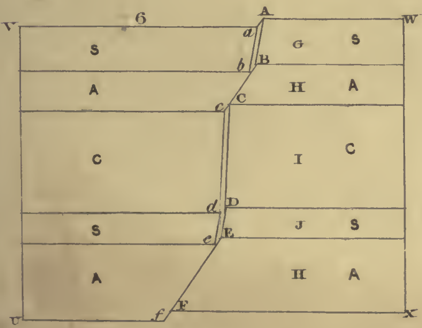
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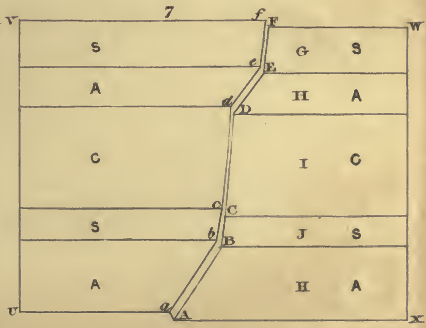
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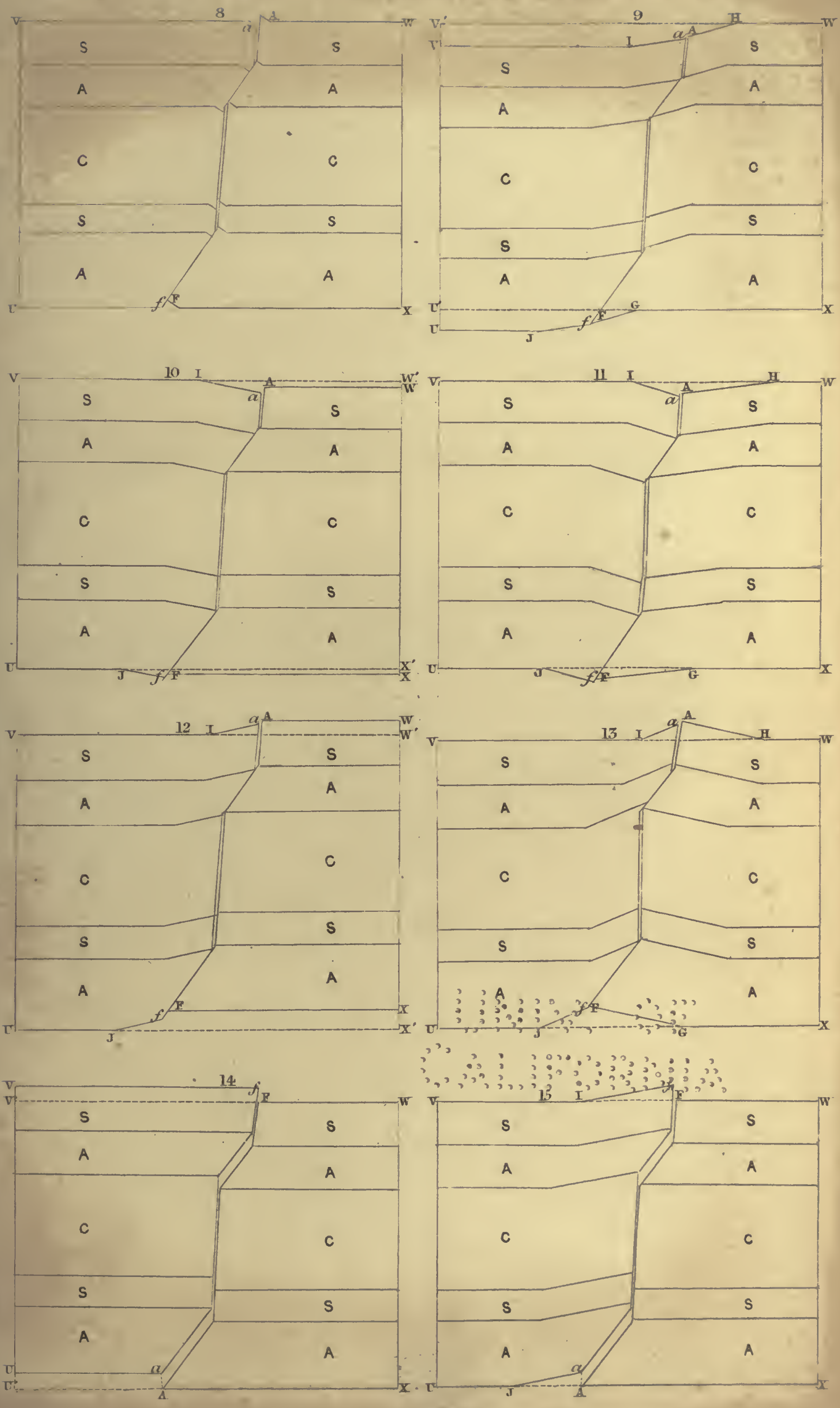
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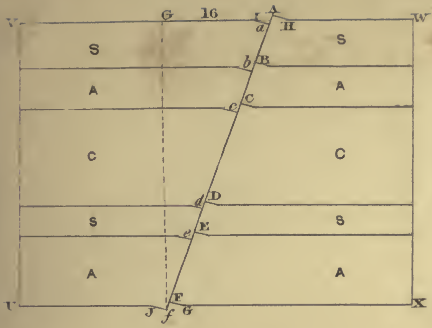
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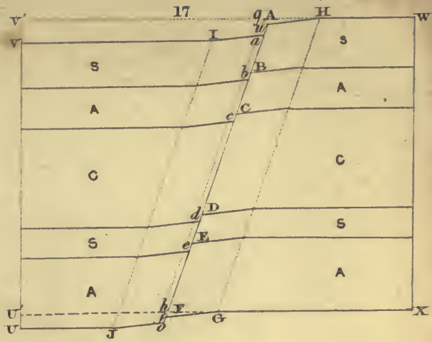
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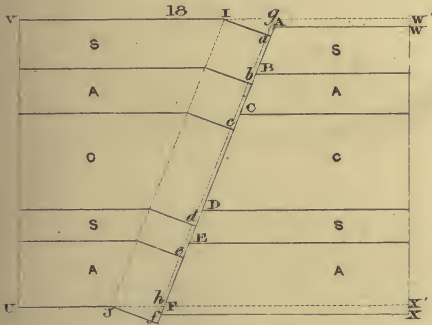
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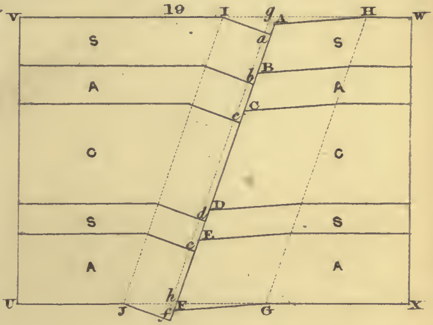
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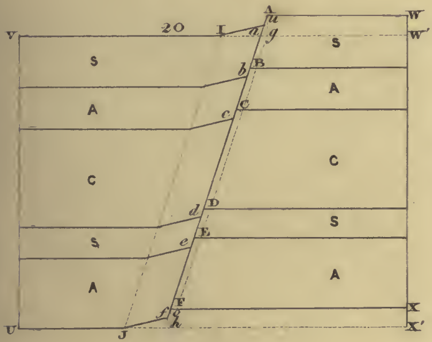
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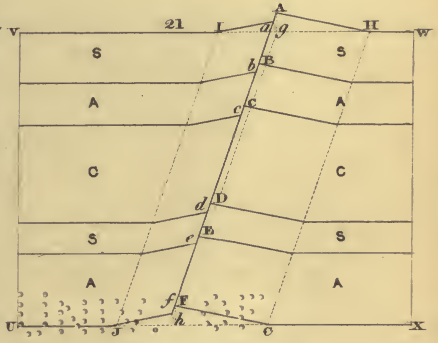
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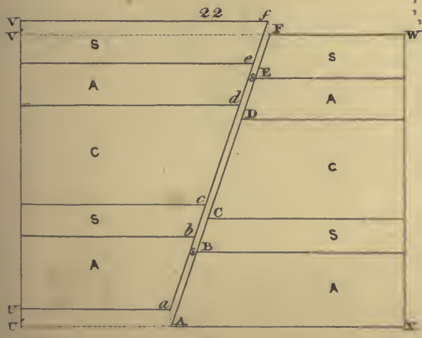
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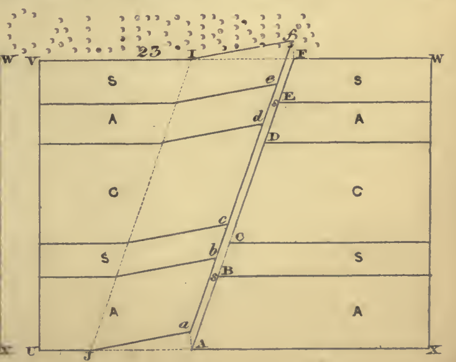
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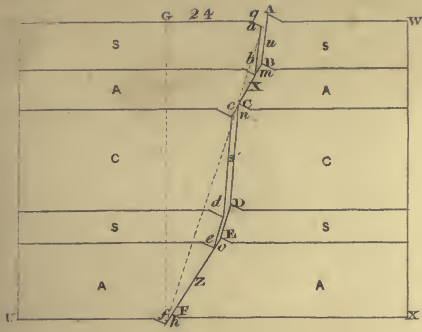

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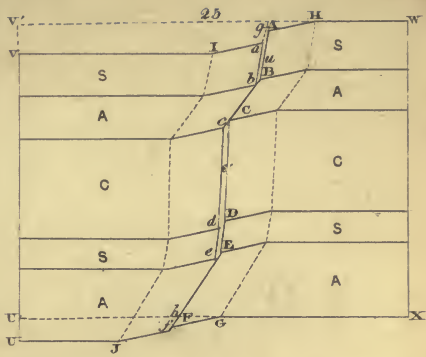

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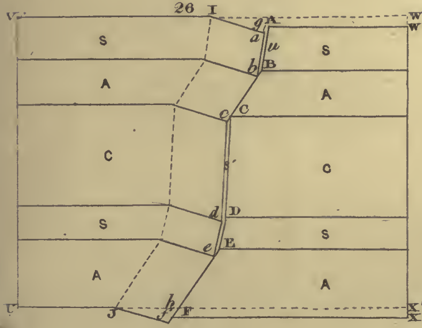

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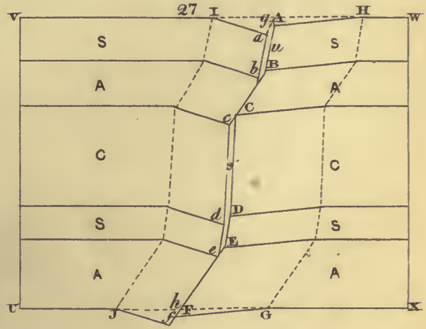

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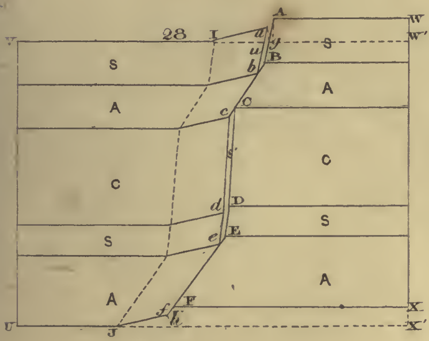

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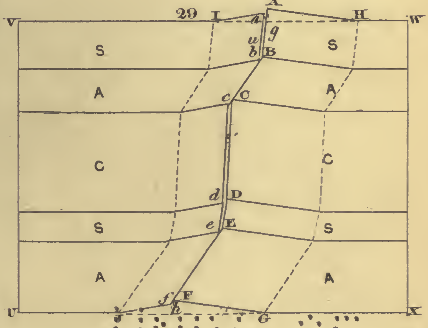

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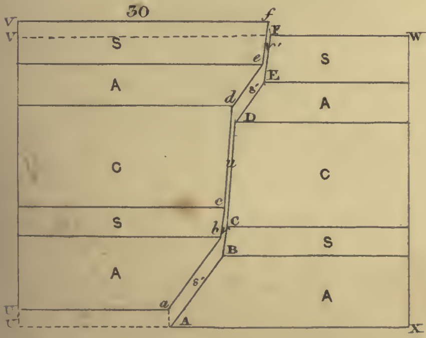

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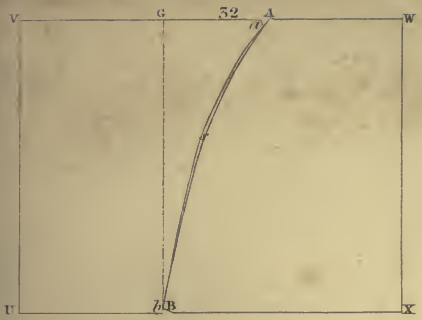
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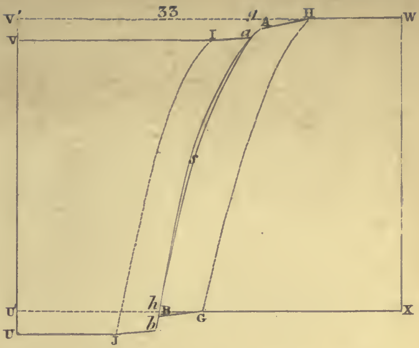
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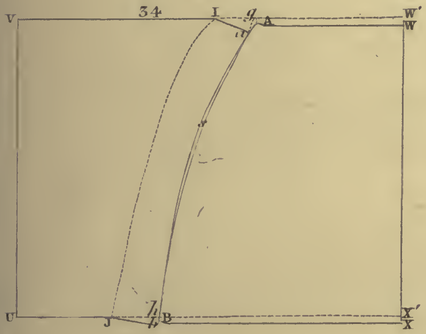
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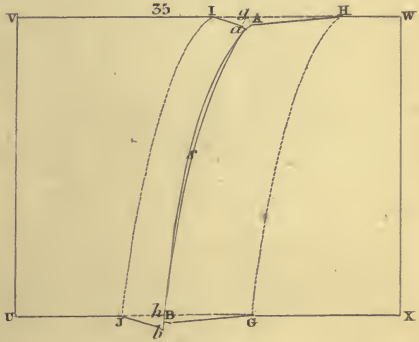
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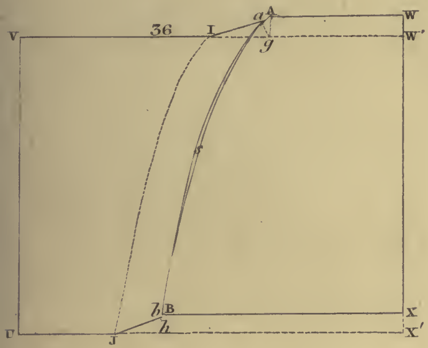
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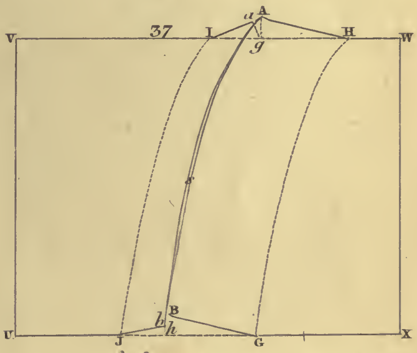
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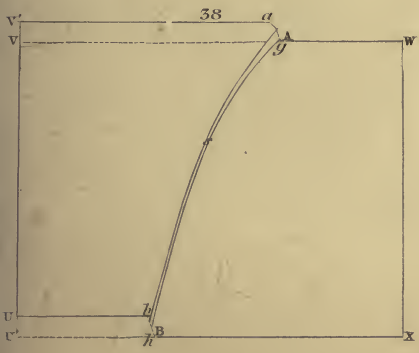
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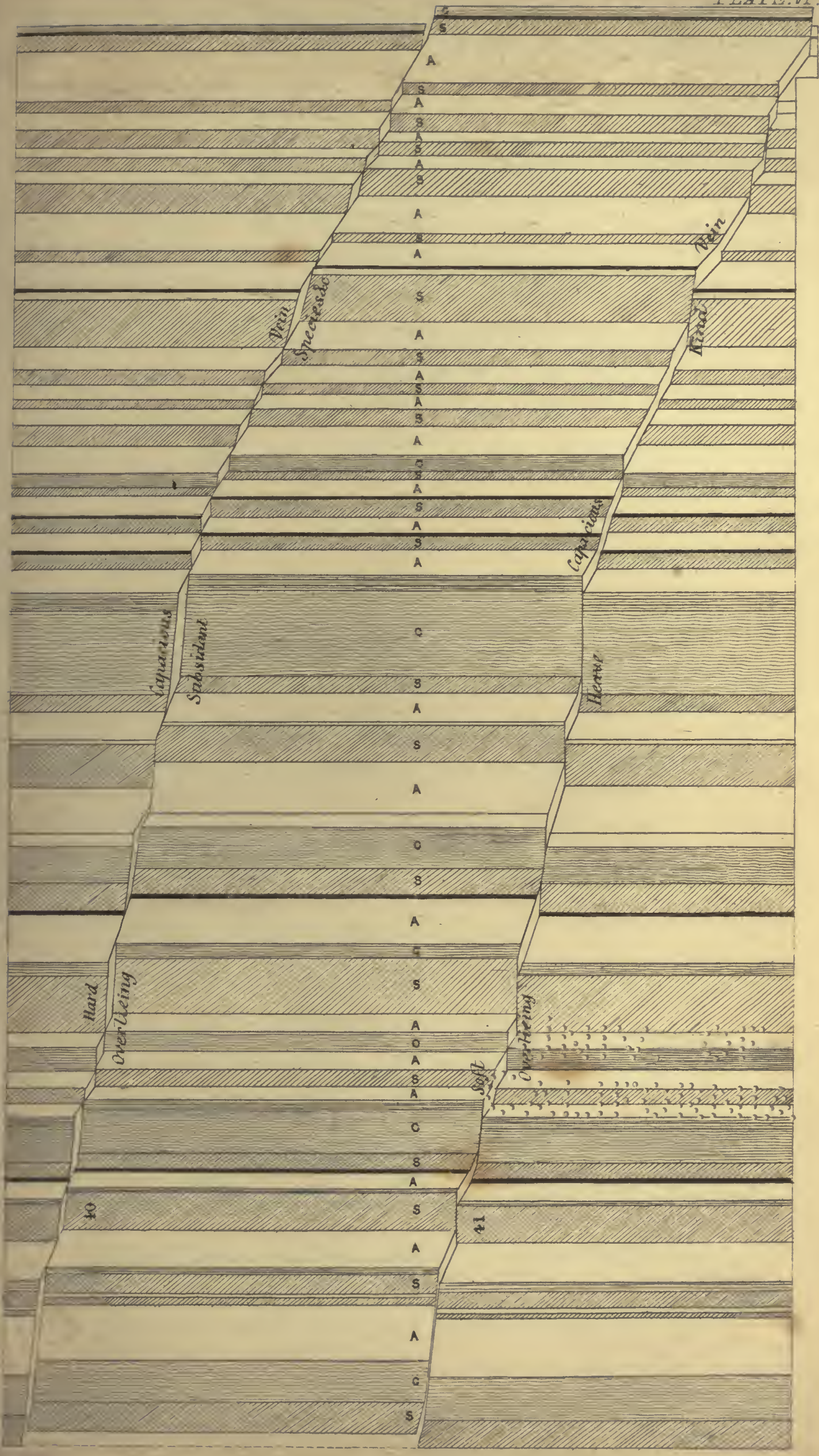
PLATE. VI.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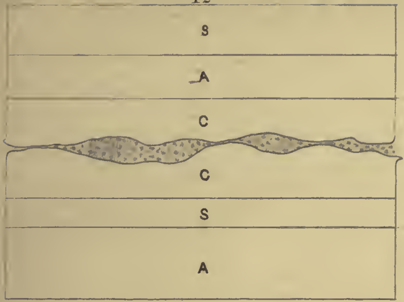


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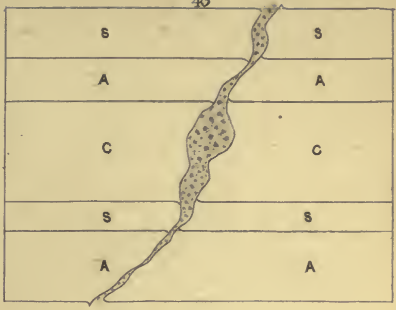


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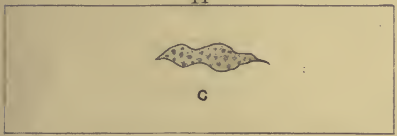


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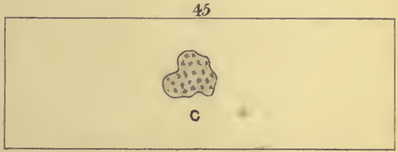


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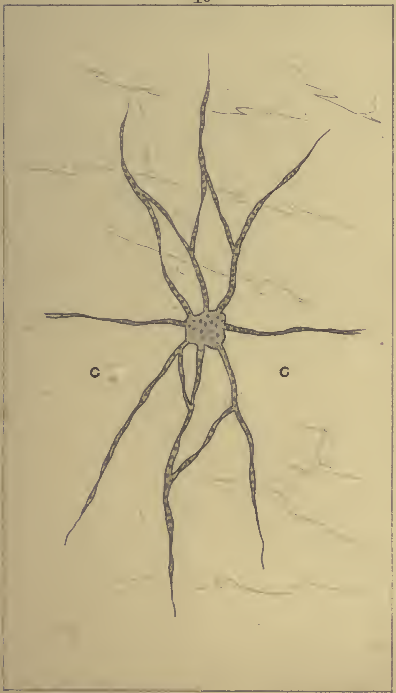


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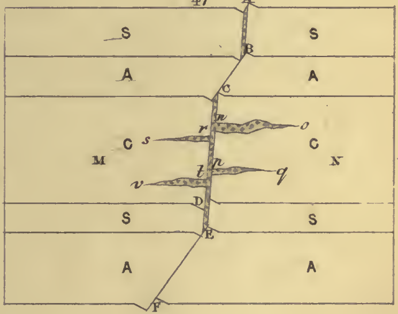


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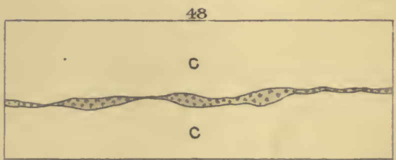

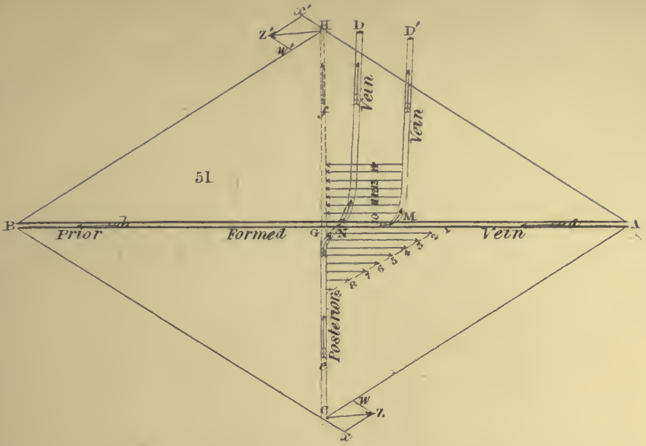
51
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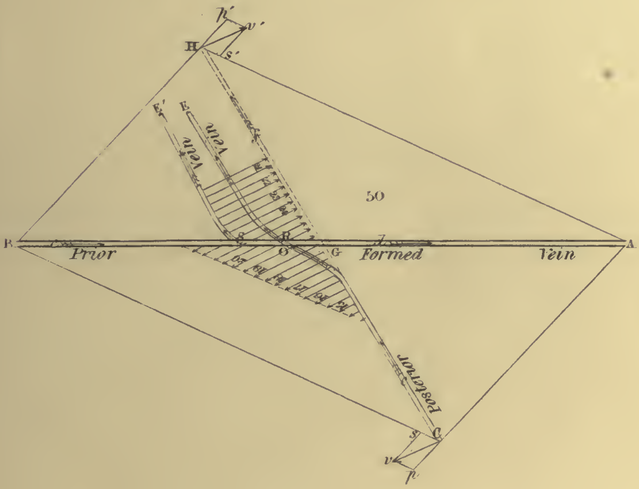
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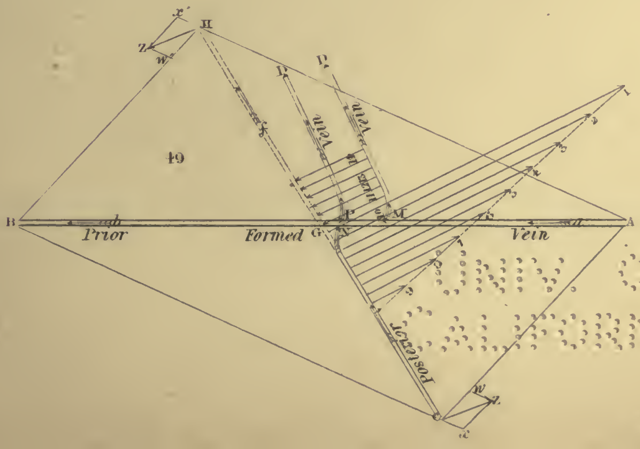
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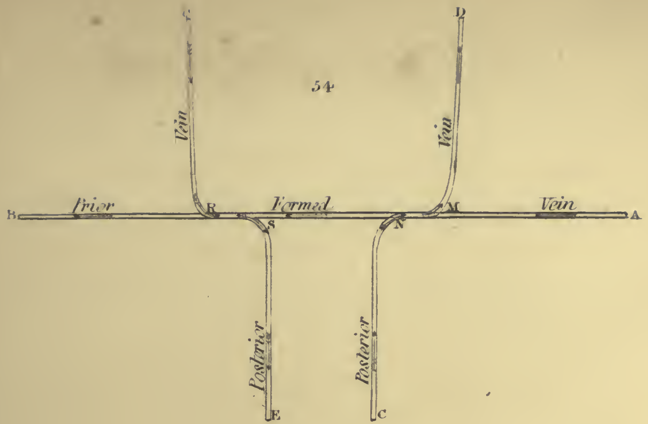
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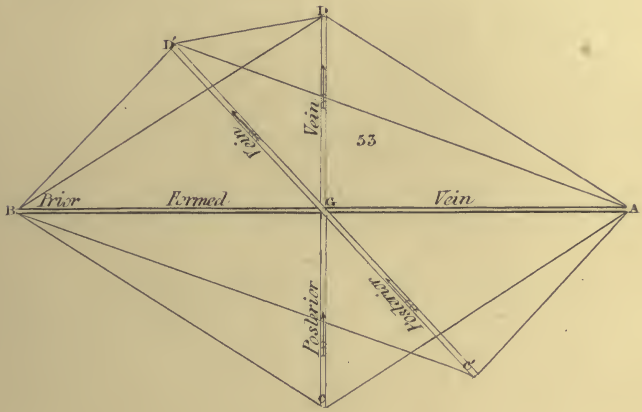
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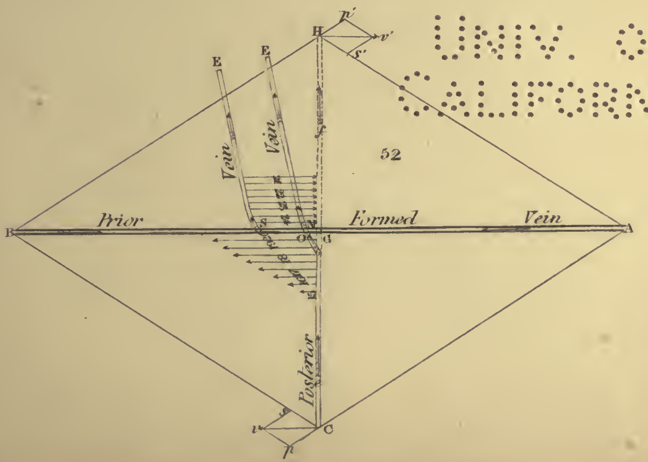
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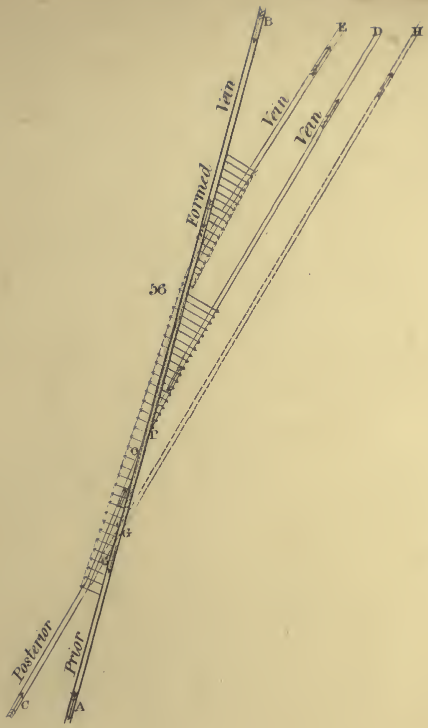
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